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A SPATIAL ANALYSIS OF LAKE SUPERIOR SHIPWRECKS:
A STUDY IN THE FORMATIVE PROCESS OF THE ARCHAEOLOGICAL RECORD

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CHARLES ALLEN HULSE

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A SPATIAL ANALYSIS OF LAKE SUPERIOR SHIPWRECKS:
A STUDY IN THE FORMATIVE PROCESS OF THE
ARCHAEOLOGICAL RECORD

By

Charles Allen Hulse

A DISSERTATION

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ABSTRACT

A SPATIAL ANALYSIS OF LAKE SUPERIOR SHIPWRECKS: A STUDY IN THE FORMATIVE PROCESS OF THE ARCHAEOLOGICAL RECORD

By

Charles Allen Hulse

9/15/77

This study describes a research effort which focuses upon the formative process of the archaeological record as it applies to Great Lakes shipwrecks, this research analyzes the spatial distribution of shipwrecked vessels from the iron, grain, and coal industries. Using these three commodities a model of hypothesized distributions and attribute relationships is created. A series of twenty-one hypotheses comprise this model and are tested within the body of this research. Such variables as vessel type, date of loss, commodity, weather, frequency of traffic, etc. are tested for their association with specific geographical locations in order to evaluate their effects upon spatial patterning of Lake Superior shipwrecks.

The testing phase of this research revealed a number of important variable associations that have a significant effect upon the formation of the archaeological record. For example, of the three commodities under consideration only the iron industry exhibited non-random patterning of related shipwrecks. The interpretation of this patterning in combination with results of other hypotheses tested is that there is a direct correlation between the capital intensity of an industry and the respective spatial distributions of associated shipwrecks. The causative mechanisms which result in this correlation are then discussed as they apply to the formation of the shipwreck

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archaeological record. The cultural and noncultural factors which account for the initial deposition of wrecks (depositional transforms) and the later decomposition of those wreck sites (archaeological transforms) are discussed in great detail as they relate to the spatial distributions revealed by this study.

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CHAPTER I

INTRODUCTION

Problem Statement

Shipwrecks in the Great Lakes constitute a major archaeological resource that is currently poorly known and understood. As archaeological sites, these wrecks offer potential for future investigations from both regional and site-specific perspectives. And as with all archaeological phenomena, they reflect the culture and behavior of a past people; a study of whom can enrich our understanding of culture process within an anthropological perspective. The development of the Great Lakes region and the subsequent industrialization during the nineteenth century has significance for a number of academic disciplines, including anthropology. Economic change, decision making, and development are important areas of study to anthropology, as they are to all social sciences. The shipping industry on the Great Lakes is one by-product of regional economic behavior that has been recorded in the present archaeological record through the occurrence of shipwrecks. From a broad anthropological approach, the study of these shipwrecks can contribute to the understanding of such cultural phenomena as economic change and the industrial process.

Despite the potential research importance of shipwrecks as archaeological sites, there has yet to be an anthropological treatment of them in the Great Lakes region. Likewise, there is currently no theoretical framework around which future shipwreck studies can be

organized. Shipwrecks differ from terrestrial archaeological sites because they reflect a set of variables that are linked to transportation rather than settlement. Additionally, underwater wreck sites have been deposited in the archaeological record by different processes than land sites. These differences suggest that shipwrecks should be viewed within a theoretical/methodological framework that both recognizes their unique qualities and directs future research toward the investigation of specialized problems. Recent academic study of shipwrecks in the Great Lakes has primarily focused only on the historical events surrounding individual vessel loss and not on broader issues. This narrow treatment fails to recognize the cultural context of vessels on their value to the interpretation of social phenomena.

The purpose of this dissertation is to apply a broad regional approach to shipwreck studies and to begin laying a foundation for the future investigation of wreck sites within an anthropological framework. Of the many questions of potential research interest, the focal point for this study is the spatial distribution of shipwrecks. This topic is particularly appropriate as an initial treatment of the shipwreck phenomena because it has value for both theoretical and methodological issues. For example, shipwrecks are reflective of a well-documented past cultural system. Since the shipping industry was known to be structured by trade routes, industrial development, and the physical environment, it would then be expected that to some extent shipwrecks would likewise be patterned. This dissertation is framed around the hypothesis that since shipping in the Great Lakes is a culturally patterned phenomena and nonrandom in occurrence, shipwrecks will likewise be patterned and nonrandom in their distribution. The question of

patterned regularities in the shipwreck archaeological record is of major importance because it will substantively affect the future treatment of shipwrecks. If shipwrecks are found to be distributed in a recognizable pattern, then future excavations, sampling strategies, etc. can take this into account and proceed accordingly. The type and extent of patterning might also be viewed as a reflection of the cultural system that shaped the development of the shipping industry; if so, patterning has potential to reveal information on culture process that is not recorded in existing documents.

As a predictive tool, the analysis of shipwreck locations may also lead toward pattern recognition that can be applied to other situations in order to locate unknown wreck sites or shipwreck clusters. For example, if this study reveals that vessels are lost in a specific pattern in relation to particular ports or geographic features, then similar locations can be sought elsewhere for like patterns. Although less important for site specific studies, this question is of greatest interest to those studies dealing with a broad regional approach to shipwrecks. Future studies involving Great Lakes shipwrecks would hopefully be based upon the degree and type of spatial patterning found in this study. Because shipwreck studies of any type are new to Great Lakes archaeology, one item of high priority is the location of sites and an understanding of the factors contributing to vessel loss and distribution. Spatial analysis is a necessary first step toward generating research interest in this little known area.

The study of the spatial patterning of shipwrecks involves much more than just locational information. Rather, it requires an investigation of a wide array of factors that contribute to vessel loss and

decomposition. For this reason, the study of the formative process of the shipwreck archaeological record is also needed to fully understand both the patterns of distribution as well as the causal variables for these patterns. In relation to this study, pattern recognition is not an end in and of itself but is one means by which a theoretical base can be initiated for the investigation of shipwreck phenomena.

For the purpose of this study, a systems approach will be used to order the data and to isolate those key variables of spatial patterning. Through a series of testable hypotheses, the relationships between these variables will be investigated and the results applied to an interpretation of spatial distributions.

In order to condense the problem into a manageable design, the geographic area selected for study has been narrowed to the Lake Superior region. This area was chosen because it was the last of the Great Lakes to be settled and is therefore historically documented in greater detail than the other Lakes. The time period considered here begins with the opening of the St. Mary's Falls Ship Canal in 1855 and ends with the second decade of the twentieth century. The year 1930 was selected as a terminal point because few shipwrecks occurred after this date because of modern advances in navigation, communication, and vessel design. During this 75 year study period, the shipping industry concentrated on the movement of four primary commodities: iron ore, grain, coal, and lumber. The first three were of importance throughout a large portion of this period, while the last achieved significance in the post-1890 period. Therefore, to facilitate comparisons between industries, only the iron, grain, and coal commodities will be dealt with in the model.

Using these three industries, this study will determine if vessels related to them are spatially patterned and if so, determine the contributing factors to this distribution. Based on the results of hypothesis testing, it may be found that some industry-related vessels exhibit patterns of loss different from the others. If so, then potential alternative explanations will be proposed for these patterns in light of the relationships between other variables tested in the analysis. It is hoped that the broader issues addressed to spatial patterning will have significance beyond this single geographic area and the time period. Because this study addresses Lake Superior industries, it must necessarily be oriented toward economics and spatial distributions. And an underlying goal of this study is to demonstrate the utility of a broad systems approach to a topic that has been investigated in the past from a historical/particularist perspective. Shipwrecks on the Great Lakes are a potential source of information on broad social issues such as economic development and technological change. In the past, these issues have been ignored by historians in favor of more particularistic treatments of individual vessels and their conditions of loss. As a result, shipwrecks are presently viewed in the same manner as historic buildings--that is, that they are valued only in terms of their unique architectural features and not in relation to the information they can provide toward an understanding of culture process and change.

In this study, the specific details of individual vessels are used to solve particular problems related to the study of spatial distributions. Such variables as vessel type, condition of loss, date of loss, industry affiliation, etc. will be analyzed as components of an

interrelated system. The shipping industry on Lake Superior was part of an industrial system that significantly changed the character of American culture in the Great Lakes region. As elements of this system, such factors as economic decision making, transportation technology, regional development, and the physical environment played a major role in shaping the transportation industry.

A locational study of shipping and shipwrecks from such a perspective requires an understanding of the processes that form the archaeological record. The system within which the shipping industry operated provides a setting for the understanding of shipwrecks in an archaeological context. A systems approach to wreck phenomena recognizes the cultural context of vessels and places specific characteristics such as spatial distributions within this broader system.

Shipwrecks Defined

The shipping industry in the Great Lakes was a complex system of transportation responsible for the movement of vast numbers of people, raw materials, and finished goods. This transportation system not only represented the economic behavior of the time but also became a developmental force that influenced the direction and future economic expansion of the region.

The Lake Superior region provided a relatively undeveloped geographic area on which the shipping industry could operate. Before the opening of the St. Mary's Canal at Sault Ste. Marie in 1855, the "shipping industry" consisted of the movement of small amounts of goods between the settlements still involved in the final years of the fur trade era. With the discovery of mineral and timber resources in the Lake Superior Region at a time when America was feeling the demands of the Industrial

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Revolution, the region became of immediate interest to the emerging class of wealthy eastern entrepreneurs. The subsequent development of the region, first in mineral resources and then in agricultural and timber commodities, resulted in the rapid expansion of transportation networks, including the railroad and shipping industries. Water transportation in particular was easily adaptable to the bulk movement of cargoes and soon became the dominant mode of transportation for such commodities as iron ore, grain, and coal.

Throughout the years of Great Lakes navigation, a great many accidents occurred involving thousands of vessels. The majority of these mishaps resulted only in minor damage and after a brief period of repair, the vessel returned to the water. Some vessels were lucky in their careers on the lakes and survived many years of service without a single mishap. Others were not nearly so fortunate and were "jinxed" with one accident after another throughout their lifetimes. Some of these accidents resulted in the partial or total loss of vessels, their cargoes, and their crews. The loss of life and property were of major interest to the many small communities of the region--and in particular to those with ties to the shipping industry. News of accidents traveled quickly and newspapers hungry for a story quickly turned mishaps into front page stories. Thus, shipwrecks became an unfortunate but integral part of society and through written and oral accounts, they became a part of the local history and tradition.

On first inspection, the meaning of the term "shipwrecks" seems quite obvious and of little need of further elaboration. However, in actuality this term has been used to represent a wide variety of mishaps varying from minor accidents to large and costly disasters. Since this

study deals ultimately with the shipwreck archaeological record, it is necessary to draw finer distinctions between the severity of loss experienced by vessels. In particular, it is necessary to separate vessel mishaps into one of three categories; 1) minor accidents where the vessel(s) involved remained afloat and did not require extraordinary assistance to make port; 2) accidents that incapacitated a vessel for a period of time (days to years) and that required special assistance for the vessel to make port; and 3) accidents resulting in total loss of the vessel so that even special assistance could not put it back into service. These three distinctions are necessary to fully understand the formative process of the archaeological record. For example, minor accidents would contribute little or nothing to the archaeological record and no traces of these actions remain today. On the other hand, accidents that resulted in total loss of the vessel comprise a major portion of today's shipwreck record. The second class of accidents is likewise of importance because it represents those vessels that were once a part of the archaeological record but were removed through such human actions as salvage. Although this type of accident is not represented today in the record, it is important to the understanding of past cultural actions as well as the process by which the present shipwreck record is formed.

This study will consider only vessels of these last two types (i.e., salvaged, total losses) because of the relative lack of accurate information on minor accidents. Since major accidents were reported widely in newspapers of the period, better information is currently available on these disasters than on the less newsworthy minor mishaps. This is not to say that minor accidents are not worthy of further

investigation, but only that they cannot be dealt with in this study because of a lack of detailed information.

Shipwrecks and Underwater Archaeology

Shipwrecks have been a part of the human experiences as long as watercraft have sailed the seas and waterways of the world. For more than nine thousand years, vessels have moved peoples, products, and ideas across space and between cultures (Bass 1972:12). It is not unusual then that water transportation evolved rapidly as an adaptation to a world that is three fourths covered by water. Over time, watercraft have proved to be the single most efficient means of transportation available. However, as long as ships have sailed the oceans, storms have destroyed those vessels. Although unfortunate for the crews of those ships, without those shipwrecks we would know very little today of these early craft and of the cultures that produced them.

Underwater archaeology had its beginnings in the early 1960s with the excavation of a Bronze Age ship in the Mediterranean (Bass 1972:9). Since then, underwater archaeology has grown rapidly as a field of study with its practitioners coming from a number of different academic disciplines. The present orientation of this field is very similar to that of European schools of archaeology whereby history, rather than anthropology, is stressed. This in part has been due to the international character of the field, with many of the first underwater excavations conducted either by European or Scandinavian teams of researchers. Likewise, the involvement of classical archaeologists with their historical or art-historical approach has added further to the stressing of this nonanthropological orientation to underwater archaeology.

The newness of underwater sites to many archaeologists has led also to an overemphasis on description and classification of marine artifacts and vessels. Those few anthropologically trained archaeologists who have entered the underwater realm have been reluctant--or unable--to address broad cultural questions using shipwreck data. In many ways, underwater archaeology today resembles American prehistoric archaeology of the mid to late nineteenth century. According to Willey and Sabloff (1974:42-87), the Classificatory-Descriptive Period (1840-1914) was characterized by the "description of archaeological materials, especially architecture and monuments, and the rudimentary classification of these." In many ways, this statement also accurately describes the large majority of current underwater archaeological investigations.

The combination of a European historical view toward archaeology and a fixation (even by many anthropologists) on the architectural description of vessels has led to a disinterest in underwater cultural phenomena by most scientific anthropological archaeologists. This is extremely unfortunate because these phenomena have tremendous potential to the study of cultural process and culture history. Until this situation changes, the underwater resources currently available for study will not be utilized to their full potential and may perhaps be destroyed by well-intentioned but poorly trained archaeologists.

In recent years, Great Lakes shipwrecks have received a great deal of attention in the popular literature but have for the most part been largely ignored by the archaeological community. This has been due to a number of factors, including: 1) lack of water-based training by the majority of land archaeologists; 2) the fact that most underwater archaeologists have their training in marine rather than fresh water

areas; 3) lack of academic programs in Great Lakes region universities; 4) the lack of conservation facilities for handling large scale underwater excavations; and 5) the reluctance of Great Lakes state governments (i.e., history divisions, museums, etc.) to become involved with a new area of study. These and other reasons have contributed to a very poor climate for the study of Great Lakes shipwrecks from an archaeological, and particularly anthropological, viewpoint. It is not surprising then that problem-oriented research in the region has not been undertaken to this point in time.

Previous Research

Outside of the fields of history and marine history, very little academic research has been directed toward shipwreck studies in the Great Lakes, partly because of the nature of underwater archaeology and its relatively expensive methods of field excavation. Despite the lack of archaeological emphasis on shipwrecks, several historical treatments of this phenomena are noteworthy. Wright's (1972) study in particular is unique because it was directed toward a broad approach to wrecks rather than the usual particularistic case study of the more "important" vessels. His study was commissioned by the Michigan Department of Natural Resources and was designed to be an inventory of vessels thought to be lost within Michigan waters. But the ultimate purpose of the study was to detect geographic areas with particularly high concentrations of wrecked ships and to provide an overall view of the shipwreck resource in the state. Based on numerous primary and secondary sources, this study succeeded in inventorying a total of 1,139 vessels believed to have been lost in state waters. Of these, 175 were believed lost in Lake Superior (Wright 1972:6). For each

vessel, characteristics such as general location, vessel name, vessel type, type of loss, date of loss, and cargo type were recorded when available. This information was then computerized and cross-tabulations were run on possible variable combinations. Unfortunately, the study progressed no further and no effort was made to analyze the results of the project nor to place the vessels into an overall developmental framework. Therefore, the Wright study was primarily descriptive; it presented information on shipwrecks but did not relate the findings to the development of the Upper Great Lakes region.

Wright (1972) also attempted to deal with the problem of location by dividing Michigan waters into 18 arbitrary zones. Locations of vessel loss were then grouped into these zones and could be correlated with other factors to form a coastal shipwreck profile, which consisted of the number of vessels lost in an area along with data on the relative vessel types, cargoes, types of loss, etc. Wright hoped that this locational study would determine general patterns of loss for specific areas. While to some extent this was accomplished, there were a number of problems associated with this approach. For example, the location zones dealt only with the Michigan waters of Lake Superior, while the study vessels had actually been a part of the total Lake Superior transportation system. By looking only at Michigan waters, Wright could have obtained a very biased representation of Lake Superior shipwrecks. In addition, the location zones were entirely arbitrary and bore no resemblance to the cultural boundaries of the shipping system. Without an understanding of the major ports, transportation networks, and natural resource locations, it would be difficult to arrive at culturally meaningful locational zones. For

these reasons, Wright's treatment of locations was necessarily limiting, although it was an excellent early attempt to deal with the question of spatial distribution of shipwrecks.

Other than this single study, no other research projects have been conducted on Lake Superior shipwrecks from anything other than a historically descriptive standpoint. Relevant historical studies will be discussed in the following section.

Sources of Data

This research project will incorporate a wide range of historical sources, both primary and secondary, into the investigation of shipping and shipwrecks in the Great Lakes, and will focus on applying the large body of historic data available on this topic to questions posed within a broader anthropological framework. Historical treatments of the shipping industry are filled with an abundance of data on vessels, vessel patterns, and shipwreck locations. What is proposed in this study is to utilize these extant historical sources as a data base for testing broader based anthropological questions. There are essentially two general categories of sources used in this investigation; 1) those sources providing information on the shipping and economic history of the Lake Superior region; and 2) those sources dealing specifically with shipwrecks and providing information about their origins and locations. Of these two types of sources, the former is by far the largest and most complete. This is because of the importance of shipping and shipping-related industry to the Lake Superior region and the extensive collections of materials available on these subjects. A wide range of primary source materials are available including commodity records, shipping records, and government statistical

abstracts. Additionally, several scholarly studies on selected topics have been published that provide an excellent base of secondary sources from which to draw. A combination of both primary and secondary sources will be used in this research project to outline the shipping industry of the period 1855-1920. In particular, such sources as Mansfield (1899), Barry (1973), Hatcher (1950), Nute (1944), Williamson (1977), and Wright (1972) provide detailed accounts of specific vessels, industries, or chronological periods of relevance to this study.

In contrast to the abundance of materials available on shipping and related industries, information on individual shipwrecks is much scarcer and difficult to obtain. The major primary source on shipwrecks in Lake Superior are the Annual Reports of the U.S. Life-Saving Service for the years 1877-1914. These reports are yearly summaries of all services provided to distressed vessels and include information on specific vessels, their cargoes, locations and damage. The Life-Saving Service divides the Great Lakes to encompass three districts--No. 10 (Lake Ontario and Lake Erie), No. 11 (Lake Huron and Lake Superior), and No. 12 (Lake Michigan). Although these records often include reports on lost vessels, they are often incomplete.

Other primary sources include newspapers, trade journals, and vessel registers, and each contain sizable amounts of data of varying quality and accuracy. There are a large number of secondary sources on shipwrecks and these too are a mixture of scholarly and sensationalized historical accounts of lost vessels. For Lake Superior, the single most significant source is Wolff's (1979) The Shipwrecks of Lake Superior. This is the most complete and well-documented treatment of

wrecks in the Great Lakes and uses an historical case study approach to examine well over 1,000 accidents. Wolff's 23 year study of Lake Superior shipwrecks includes a wide variety of information drawn from primary sources such as those previous mentioned. Because of its high degree of scholarship, this study will serve as the major source of shipwreck data for this research project. Other secondary sources such as Heden (1966) and Winkelman (1971) will be used as supplementary data whenever needed. When combined, these sources offer the most reliable and complete data presently available on the subject.

Therefore, the main emphasis of this dissertation will be the application of existing historical data to questions relevant to the study of spatial distributions of wrecks. Although this approach relies on the quality of available sources, this does not appear to be limiting since they are complete enough to provide the data needed to test hypotheses posed in this investigation. Those hypotheses and the model around which they are organized will be discussed in detail in following chapters.

CHAPTER II

PHYSICAL ENVIRONMENT OF LAKE SUPERIOR

The physical environment of the Lake Superior region had a major effect on the type, extent, and rapidity of its settlement and development. The location of natural resources, population centers, and transportation lines encouraged development of certain sectors of the region over others. This chapter outlines the physical geography of Lake Superior and its coastline, illustrating the prominent features that affected navigation and shipping.

Physical Geography and Navigation

With a surface area of approximately 32,000 square miles, Lake Superior is the largest body of fresh water in the U.S. Its greatest length from east to west is about 350 miles, while the point of greatest width is roughly half as long. The altitude of the lake surface averages 600 feet above sea level, 20 feet higher than Lakes Michigan or Huron at 580 feet (Sommers 1977:43). Until the construction of a lock system at Sault Ste. Marie in 1855, this difference in levels created a barrier to the direct access of the lake. During the last century, the level of Lake Superior has remained more stable than the other Great Lakes, with a maximum variation of only 2.6 feet. These yearly variations are due to a number of factors, including temperature and rainfall and may have had an impact on navigation by making some harbors and ports less accessible during low-water periods.

Lake Superior is also the deepest of the lakes; its maximum depth of 1333 feet is found in the eastern portion of the lake. While variations in depth (over 30 feet) would have little direct impact on navigation, they would definitely play a role in the salvage and retrieval of lost vessels and cargo.

The waters of Lake Superior are clearer and colder than the other Great Lakes. Average water temperature at Marquette, for example, ranges from a high of 60° F in August to a low of 34° F from December through March (Mansfield 1899:46). During the winter months, it is not unusual for the lake to freeze over, either totally or partially. Even in the summer months the water temperature under the surface is greatly reduced for each 20-foot increment of depth, so that below 200 feet the temperature remains a constant 39°F. These temperatures, along with the fresh water, combine to produce conditions perfect for preservation of organic materials.

Lake Superior harbors are particularly important to lake navigation by providing terminal points for docking as well as a safe refuge in case of storms. An early traveler on the lake commented that

The natural harbors of this lake are not numerous, but on account of its extent and depth it affords an abundance of searoom, and is consequently one of the safest of the great lakes to navigate. The only trouble is that it is subject to severe storms which arise very suddenly. Often have I floated on its sleeping bosom in my canoe at noonday and watched the butterfly sporting in the sunbeams; and at the sunset hour of the same day have stood in perfect terror upon the rocky shore gazing upon the mighty billows careening onward as if mad with a wild delight, while a wailing song, mingled with the 'trampling surf,' would ascend to the gloomy sky (Mansfield 1899).

This quotation graphically illustrates the relative lack of harbors as well as the urgency of finding refuge from storms. Following is a listing of the principal harbors found on Lake Superior.

Table 1. Lake Superior Harbors

Sault Ste. Marie, MI, ONT	Eagle Harbor	Duluth/Superior, MN/WI
Grand Marais	Ontonagon	Two Harbors
Munising	Ashland, WI	Grand Marais, MN
Marquette	La Pointe, WI	Port Arthur, ONT
L'Anse	Bayfield, WI	
Copper Harbor	Portwing, WI	

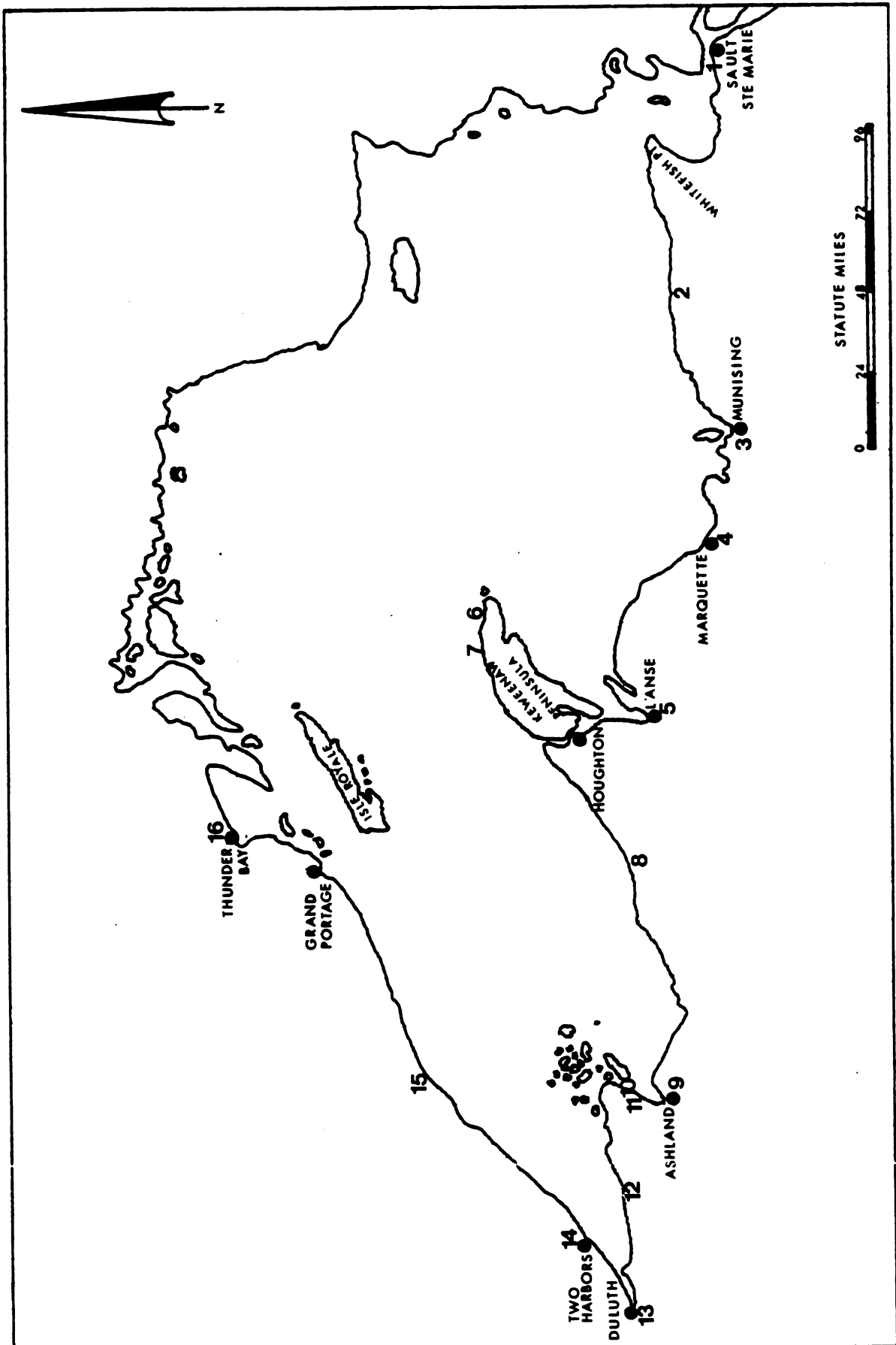
These harbors constitute the major geographic areas where a number of factors combine to allow for port facilities. Such elements as water depth and shelter are essential for the construction and use of docking facilities. From the list above, it can be seen that on the entire north shore of the lake there are only three harbors---Two Harbors and Port Arthur---compared to 14 (88 percent) on the south shore. In an historical sense, this geographic discrepancy has had a major effect on the settlement of the respective shores of the lake (see Figure 1).

In times of storms, vessels on the lake would have attempted to either "weather them out" or head for safe harbor. Because of the relative lack of facilities for such a large geographic area, the next best alternative would be to seek shelter wherever possible. Protected areas are those locations that provide vessels some relief from the winds and waves associated with the dangerous northwest storms of the region. When a vessel is caught on the open lake in a storm too violent to ride out, it seeks one of these sheltered areas, which are predominately on the leeward side of points, peninsulas, and islands.

Navigational hazards on Lake Superior are difficult to define since this depends on human behavior as well as geography. For example, those same islands that provide shelter from storms are also potentially hazardous to navigation under other circumstances, such as

1. Sault Ste. Marie, MI, ONT
2. Grand Marais, MI
3. Munising, MI
4. Marquette, MI
5. L'Anse, MI
6. Copper Harbor, MI
7. Eagle Harbor, MI
8. Ontonagon, MI
9. Ashland, WI
10. La Pointe, WI
11. Bayfield, WI
12. Portwing, WI
13. Duluth/Superior, MN/WI
14. Two Harbors, MN
15. Grand Marais, MN
16. Port Arthur, ONT

Figure 1. Lake Superior Harbors



fog. Therefore, hazards are relative phenomena dependent upon a number of factors that come together at a single point in time. Shoals found along large portions of the coastline present a hazard to navigation only when vessels stray outside of their designated navigational lanes. In geographic areas where a course change is necessary (e.g., for rounding a point, or avoiding an island), weather conditions are hazardous only when they reduce visibility or maneuverability. Sometimes ships might actually seek out hazardous areas: intentional grounding could prevent total loss to the vessel and crew when foundering was the only other alternative; Wolff (1979) discusses numerous instances when these intentional groundings became necessary. So navigation on Lake Superior was affected by a wide array of both environmental and cultural factors; shipping and the resultant loss of vessels was not a function purely of climate or geography.

Weather and Navigation

Throughout the history of Great Lakes navigation, weather had a major influence on the movement of ships and cargo across this broad geographical area. Weather can be viewed in two ways: as a commercially restrictive force and as a randomizing element in the navigation process. In terms of its restrictive or constraining feature, the single element of greatest influence was the season of navigation on the lakes. The length of the season had a major effect on the amount of goods, the number of vessels, and the number of round trips possible in a given year. Table 1, Appendix A, presents a listing of the length of navigational seasons on the lakes for the years 1855-1930. These dates represent the recognized opening of the Sault Canal and pertain especially to the traffic from Lake Superior to southern ports.

During seasons of short duration, the traffic on the Lakes is congested into a shorter period and vessels are anxious to sail at the beginning and ending of the navigation season. In addition, in an extremely short season with an early winter, economics often force vessels into attempting a final round trip when in longer season years, this would not be necessary.

The weather also influences traffic on the Lakes through storm and fog patterns. Storms on the Lakes can approach those of the oceans in both intensity and duration. But the Lakes present certain features unique to this geographic area. Generally, most major storms on Lake Superior occur during October and November, while the best weather is in the months of July and August (Mansfield 1899:45; Townsend and Ericson 1978:123-125). Although much more frequent in October and November, storms may arise any time throughout the year. Before the advent of ship-to-shore communications in the first decade of the twentieth century, ships were more or less dependent upon the judgment of the captain and crew for predicting shifts in weather. Even with these communication facilities, many ships are caught in rapidly rising storms at locations that offer no refuge. So it is a matter of chance exactly when and where storms will interfere with navigation and possibly result in vessel loss. Most of the severe storms come from the north, as opposed to the prevailing winds that normally come from the southwest or west (Mansfield 1899:47). This northerly shift of wind is particularly dangerous because large fluctuations in water level occur over the unrestricted water, sometimes resulting in seiches and surges. These are particularly dangerous in shallow areas along the coastline, such as in Keweenaw Bay.

As construction of steel--and larger--bulk carriers began and as weather prediction became more scientific, the number of vessels lost in storms began to decrease. With the advent of radar as standard equipment in 1940, collisions and groundings were significantly reduced. For example, Lake Superior collisions accounted for eight of 136 losses during the period 1835-1900, and from 1900-1943, this number increased to 13 of 143. But with radar after 1943, no vessels have been lost in collision (Wolff 1962:136). Fog was one major cause of collision. In the Great Lakes, fog is most prevalent in the northern regions, such as Lake Superior, where the water stays colder. It occurs most often during a warm trend in the spring when the water temperature lags behind the temperature of the surrounding land. By summer, the water temperature has warmed to a point where fog is not a problem (Townsend and Ericson 1978:125-126). Generally, fog is a problem within five nautical miles of the shoreline and does not pose a major threat on the open lake. Beyond its visually limiting effect, one characteristic of fog, is its abberation of sound. Ship and fog signals on the Lakes can easily be misjudged so that the sound appears to be coming from a different direction and distance than it actually is (Mansfield 1899:50). Possibly for this reason few fog signals were ever installed on Lake Superior. The Coast Guards Light list carries this warning:

Fog signals depend on the transmission of sound through air. As aids to navigation they have certain inherent defects that should be considered. Sound travels through air in a variable and unpredictable manner. Mariners are warned that fog signals can never be implicitly relied upon (U.S. Coast Guard 1970), (Holland 1972:202-203).

Collisions and groundings in fog remained a major problem on Lake Superior until the 1940s.

Environment and Vessel Loss

Collisions were only one of four major causes of loss on the Great Lakes; fire, foundering, and groundings were also major forms of vessel loss that took a heavy toll. Fire was more common to certain types of vessels than others. Early propellers, steamers, and tugs were particularly susceptible to fire because their propulsion systems were dependent on wood- or coal-fired boilers (Wright 1977:12). Naturally, they presented a constant hazard, especially in stress situations.

The other disasters--founderings and groundings--were common to all types of vessels but particularly to those sailing ships with a greater dependency on the weather. For example, schooners, which were generally small in size, were common on the lakes before the institution of communication devices and many modern navigational aids. Many sailing ships were lost through foundering or grounding in the intense storms of Lake Superior. With the advent of larger and safer vessels, losses in storms were greatly reduced. Between 1920 and 1940, the institution of separated navigation lanes and radar eventually eliminated losses due to collisions (Wolff 1962:137). In this same period, founderings were also reduced. Ice build-up from winter storms, shifting of cargo in storms, etc., all played a role in founderings. Technological advancements in vessel design and cargo handling made the modern bulk freighters very stable in the water. By the 1940s, ship loss due to any type of disaster was an unusual occurrence. No single factor was responsible for the improvement of vessel safety, rather it was a combination of different but related phenomena that played a major role in this regard. Larger and more stable vessels, better weather reporting and communication systems, radar, and well-defined

navigation lanes all helped eliminate major disasters on the Great Lakes.

Until the 1920s, the actual navigational routes on the Lakes were informally derived. At that time, sailing lanes separated for upbound and downbound traffic became separated in order to minimize the danger of collisions (Johnson 1948:118). Before 1920, navigational routes were charted by individual vessels or companies dependent upon the destination and stops a vessel had planned. Because of the natures of cargoes and the specifics of each industry, there were major differences in navigational routes between shippers of different commodities. Therefore, routes traveled by carriers of package freight were different from ore carriers because they had different markets to cover and variations in points of origin and destination. An ore carrier downbound from Marquette would plan a direct route to Lake Erie to minimize time and expense. A package freighter traveling the same route might stop at numerous intermediate points to load and unload cargo, covering different routes in the process. The same can be said for vessels carrying other commodities like lumber, grain, salt, and stone, all common to Lake Superior traffic.

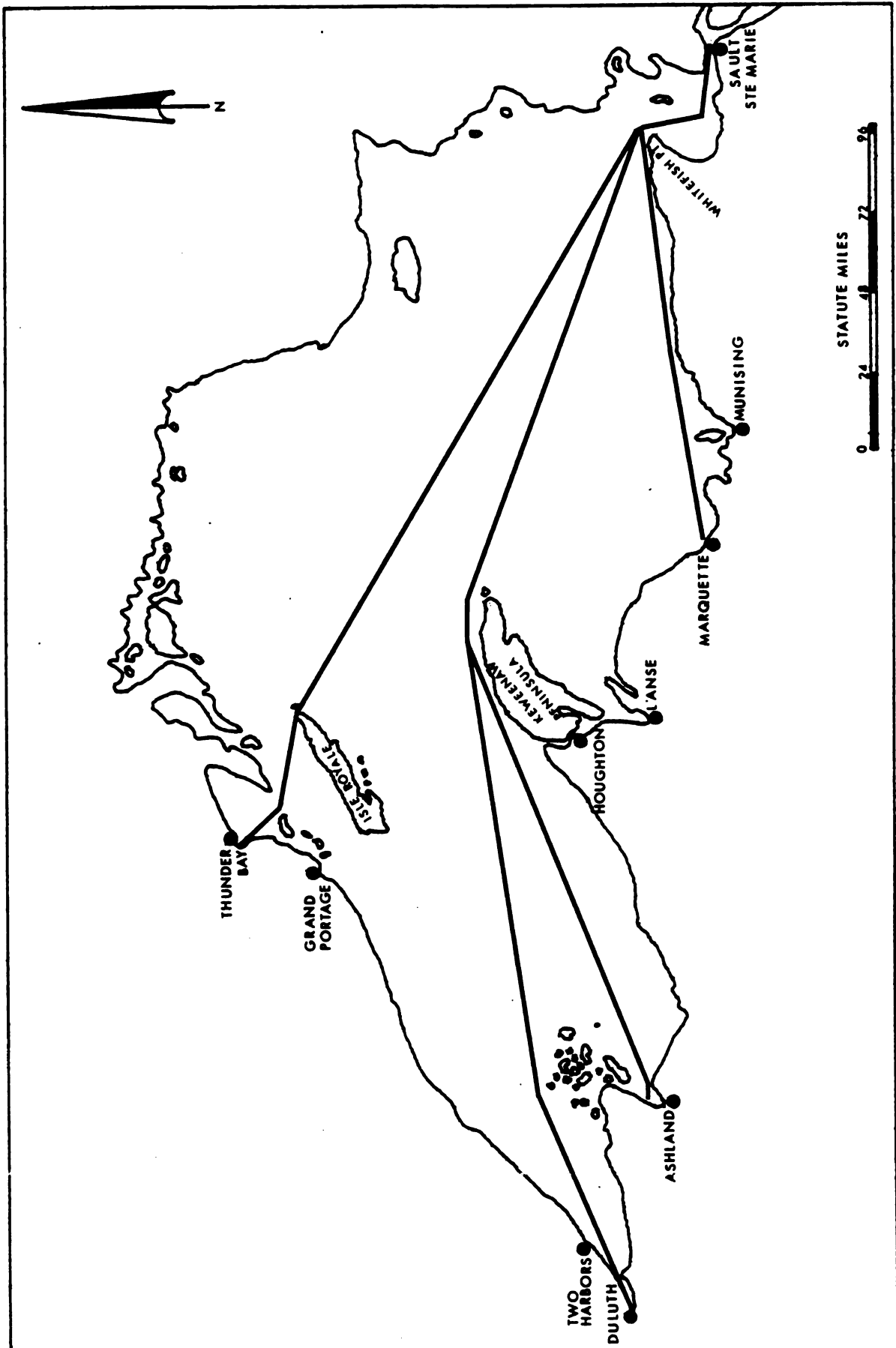
Before the establishment of set navigational lanes, the judgment of the ships' masters (along with some basic rules for passing, etc.) were the only regulations imposed on vessel traffic. This presented few problems when the weather was clear and visibility good but in storms or heavy fog, the danger of collision or grounding was very real. The greatest dangers occurred where navigation was so restricted that traffic concentrated in certain areas. The geography of Lake Superior is such that at some points, maneuverability is restricted

because of channel depth or navigational hazards. Five areas in particular have this concentrating effect: 1) Duluth/Superior to the Apostle Isle; 2) Ashland past the Apostle Islands; 3) Keweenaw Peninsula; 4) Whitefish Point; and 5) Southern Whitefish Bay to Sault Ste. Marie. In these areas, vessels might change course several times to maintain a direct route across the lake. Also, ship masters seek to minimize the distances they must travel because of the economics of lake carriers. Time lost going too far out when rounding the Keweenaw is lost money and broken schedules at the furnaces on Lake Erie. Some concentration of traffic is therefore a result not only of geographic constraints but also of maximizing economic behavior by vessel captains. This congestion of traffic around harbors significantly increases the probability of vessel loss due to collision or grounding.

Ships associated with the bulk cargo industries followed a general pattern of navigation consistent with the developments of the shipping industry as a whole. When the iron industry opened new ranges for mining, new lines of transportation developed accordingly. Within this major overall shipment pattern, individual ships varied little in regard to the specific routes traveled on Lake Superior. The downbound cargoes of pig iron or iron ore traveled routes designed to maximize speed and to minimize distance in the journey to Lake Erie ports. Vessels traveled straight courses (wind and weather permitting) that took them across the open lake. Upbound vessels usually brought cargoes of coal, general freight, and sometimes passengers as vessel design permitted. These trips were normally made on similar routes that brought the vessels slightly closer to shore on the upbound leg of the journey. The navigational lanes that were eventually established

through federal regulations are very similar to the historical routes established during the major period of ore shipment beginning in 1870. Figure 2 illustrates the major modern navigational routes on Lake Superior.

Figure 2. Lake Superior Transportation Routes



CHAPTER III

HISTORICAL BACKGROUND

This chapter introduces a general history of the Lake Superior shipping industry and discusses the specific development of the iron, grain, and coal industries as they relate both to shipping and to the development of the region. Because the shipping industry of Lake Superior was so highly interrelated with the various commodity trades, there was a great deal of overlap between these two areas. Such factors as technological change in vessel construction and navigational improvements will also be discussed as they apply to the overall development and evolution of the shipping industry.

This chapter is not meant to be a complete treatment of this enormous topic, but rather is a synopsis of salient points relevant to the problem under consideration. From this summary, general patterns of chronological development and shipping history can be drawn that will be used to provide the cultural context for examining shipwrecks. The historical factors that affected production, transportation, and distribution of various commodities also affected the characteristics of resultant vessel losses. In order to understand the interrelationships between factors influencing the shipping industry, a historical perspective is required.

Early Development and Transportation

Early explorations into the Lake Superior region were an outgrowth of overall development and settlement of the Great Lakes in the first half of the nineteenth century. Earlier experiences in the Lake Superior basin, such as the fur trade and the War of 1812, succeeded in bringing the extensive timber resources to public attention. In the succeeding several decades after the War of 1812, the character of the eastern United States underwent a rapid change because of industrialization and the associated growth of urban areas. The Great Lakes were minimally involved in the first wave of the industrial revolution, and it was not until the appearance of lake steamers in 1818 and the opening of the Erie Canal in 1825 that states of our present Midwest, such as Ohio and Michigan, were settled to any great degree (Bald 1954:152).

With the opening of the upper lakes to an eastern transportation network, development accelerated rapidly in terms of both population expansion and preindustrial commercial ventures. Before 1830, commerce west of Detroit was primarily involved with the Indian trade, while the trade east to Buffalo consisted of eastbound fish, furs, corn, and whiskey and westbound cargoes of passengers and general merchandise (Mansfield 1899:182). With Buffalo as the major eastern port, it became the early commercial center for Great Lakes traffic and development. By 1832, more than half of all westbound immigrants arrived via Great Lakes waterways. Immigrants from Europe and the northern states used the Great Lakes transportation system almost exclusively (Mansfield 1899:183). Much of this western movement resulted from the investment in the upper Great Lakes region by wealthy eastern land speculators and from the corresponding development of industry and commerce along the

Lakes. During the period 1830 to 1840, the population of Michigan rose from 31,639 to over 212,000, and by 1850 to just under 400,000. This immense growth was concentrated in rural agricultural areas along major transportation routes such as the lakes and major rivers.

Throughout this period, water transportation played the major role in the distribution of people and goods across the region because of its relative inexpensiveness compared to overland travel. Despite its great importance, until the mid-1850s the water transportation system on the upper lakes was still in its infancy in comparison to the lower lakes. By 1840, only eight vessels were making the trip from Buffalo to Chicago on a regular basis (Mansfield 1899:185).

Overland transportation was also on the rise at this time, providing substantial competition for the passenger trade. Roads from Detroit to Saginaw, St. Joseph, and Chicago were completed by the mid-1830s and stage service was established along these lines (Parkins 1918:258-261). Before the railroads arrived, these inland roads served as the only outlets for surplus agricultural products for much of interior southern Michigan. Detroit was the nucleus from which these roads radiated and became the major marketplace as well as the supply station for the state (Parkins 1918:262).

Beginning in the 1840s, the building of railroads in Michigan became a major industrial venture. Immediately upon completion of the Michigan Southern and the Michigan Central railroads to Chicago in 1852, the railroads became major competitors of the steamships companies for business. Having the advantage of year-round service, they soon replaced water transportation as the leader in passenger traffic (Mansfield 1899:191). This had a major effect on the shipping

industry in terms of the movement of people but had no effect on the movement of bulk goods. Rates for freight remained considerably less for water transportation than for any form of overland travel.

Even though Michigan saw rapid expansion in both population and transportation, it remained an agriculturally oriented state before the Civil War (Bald 1954:249). The period of 1830-1855 could therefore be regarded as a preindustrial frontier of the industrial revolution which was rapidly pushing westward from eastern centers. This frontier followed transportation routes based on water and rail lines, and development followed quickly in its wake.

In the eastern United States during the mid-nineteenth century, the industrial revolution changed many industries through the introduction of the factory system. The seemingly endless expansion of railroad networks in both the east and the west also transformed the timber and iron industries to meet increasing industrial demands. At that time, iron production was centered in Pennsylvania where abundances of hardwood forests, coal, and iron ore were in close enough proximity to each other to make it a profitable undertaking. The hardwood forests were cut and reduced to charcoal, which produced a high quality, malleable wrought iron. But the eastern forests did not last long and by 1855, coal-smelted iron had for the first time surpassed charcoal iron in percentage of total output (LaFayette 1977; ix). By 1850, the demand for iron created a market situation that pushed the price of finished iron into a steady rise that lasted throughout the century. When A.W. Burt discovered iron in the Lake Superior region in September of 1844, a number of entrepreneurs soon recognized the significance of his find.

The Iron Industry

Just before the discovery of iron ore near Teal Lake (southwest of Marquette), a company was forming to mine copper. When word of the discovery became known, this company shifted its interest to iron and in July of 1845, the Jackson Mining Company was formed. In 1847, they began mining operations and erected a Catalan forge. Destroyed by a flood later that year, the forge was rebuilt in 1848 and continued an unsuccessful commercial operation until 1850, when it was abandoned. In 1849, two eastern industrialists organized another company interested in iron production, naming it the Marquette Iron Company. This company built a forge in 1850 and by the next year, produced iron at the rate of about 20 tons per week (LaFayette 1977:2).

The Cleveland Iron Mining Company was founded in 1847 to buy and explore iron ore lands. In May of 1853, the Marquette Iron Company sold out to the Cleveland Iron Mining Company (Bald 1954:241). Like the other companies before it, the Cleveland Iron Company was also involved with the production of iron in forges as well as with limited shipment of ore. The first shipment of iron ore from Lake Superior occurred in July of 1852 when the Marquette Iron Company shipped six barrels of ore to New Castle, Pennsylvania. The following year, the Cleveland Iron Company shipped an additional 152 tons of ore to Sharon, Pennsylvania (Hickok et al. 1938:17).

Those years from first discovery of iron ore to 1855 represent an early experimental phase in the iron industry, when mining technology, transportation, and production techniques were based on trial and error. This was primarily because of the lack of available information from which economically profitable decisions could be made. At the center

of this decision making process was the transportation problem, and this single factor was of greatest importance throughout the duration of the iron ore industry (Hatcher 1950:62). For example, transportation involved 1) transportation of ore from the mines to either forge sites or docks, 2) transportation of charcoal to the forge sites, 3) transportation of finished iron (or ore) to southern markets, and 4) transportation of ore or iron from southern docks to furnaces or mills. These transactions include the problems of transshipment of each change of transport. Before 1855, the iron companies experimented with their various options--chiefly, whether it would be more economically profitable to produce ore locally and ship finished iron to southern markets, or concentrate on shipping bulk ore only. The shipments of ore in 1852 and 1853 were most likely trial runs testing out the latter option.

As early as 1837, Governor Mason of Michigan wanted a canal built around the rapids of St. Mary's River, but it was not until 15 years later that Congress finally authorized the construction of this canal (Hickok 1938:17). Work on the canal began in June of 1853 and was finally completed in May of 1855. Before the opening of the St. Mary's Canal, only a dozen or so vessels sailed upon Lake Superior, all of which had to be dragged over the portage around the Sault (Bald 1954:243). Many authors have discussed in great detail the actual building of the canal at Sault Ste. Marie, and their thoughts, will not be reiterated here in great detail (see Neu 1953:25-46). In general, the completed canal consisted of two locks, each 350 feet long, 79 feet wide, and 13 feet deep (Bald 1954:244). The opening of the canal at the Sault provided the first opportunity for any real economic

investment or development in the Lake Superior region. Before 1855, vessels carrying industrial raw materials such as ore or timber were forced to unload their cargoes at the falls and transport them across the portage to awaiting vessels on the other side. Unloading and loading in this manner was accomplished by means of wheelbarrows and hand labor, and the costs were so expensive as to make any regular service of this nature economically unprofitable.

The Sault Canal changed this economic picture entirely, totally eliminating transshipment costs at the falls. Decision makers in the iron industry then faced a new economic problem. Again, the question was whether it was more feasible to produce iron at local furnaces or concentrate upon shipping ore to southern operations. The period 1855 through the Civil War was one of high investment in the iron industry in mining, iron production, and transportation. For example, the mining town of Negaunee consisted of six rough-hewn log houses and a dozen workers in 1855 when the canal opened. Less than four years later, the population had risen to more than 300 workers. After ten years of slow growth, this population boom was a direct repercussion of the growing need for iron and the opening of the Great Lakes Waterway through the Sault (Hatcher 1950:81).

Population expansion in the mining areas of the Marquette Range was a reflection of overall expansion of the mining and refining industries. In 1855, a major push to improve overland transportation from the mines to Lake Superior (a distance of 10 to 15 miles) began. A plank road from Ishpeming to Marquette was built that year and in 1857, it was fitted with tracks for a steam railroad system owned by the Iron Mountain Railroad Company (Hatcher 1950:72). Improvements in

transportation of ore greatly decreased freight rates from the mines to Marquette and from Marquette to the major Lake Erie ports. Table 2 shows this decrease in rates from 1855-1858.

Table 2. Freight Rates (Hatcher 1950:82)

Year	Mines-Marquette	Marquette-Lake Erie Ports
1855	\$3.00/ton	\$5.00/ton
1856	\$1.27/ton	\$3.00/ton
1857	\$1.27/ton	\$2.67/ton
1858	\$.87/ton	\$2.09/ton

This decrease in freight rates illustrates the impact of the Sault Canal and improved local transportation on the economic picture at that time.

The passenger trade also changed greatly with the opening of the canal. The shipping industry soon regained the advantage held by the railroads as far as the western traffic was concerned. This provided a steady supply of immigrant labor to all parts of the Lake Superior shoreline, so that this key element was never a major factor in limiting the growth of the iron industry.

In 1856, the first movement of goods occurred from the Great Lakes directly to Europe. This event is noteworthy in that America was rapidly developing its international market at the time when earlier industrial powers such as England were declining in world economic influence. An implication of this is that the economic decision makers in the Lake Superior region had—with the opening of the Sault Canal, at least—the possibility of connecting with world markets at some future point in time. Investment in timber and mineral resources increased across the region until the overextension of credit resulted in the Panic of 1857, which caused a temporary but measurable slowdown in

growth. The impact of the "Panic" was hardest felt in the iron industry by a marked depressed demand for iron and iron ore; even the Pittsburgh mills were forced to temporarily close (Hatcher 1950:88). Fortunately for the iron industry, this depression was short-lived and by the following year, production was again on the rise. The panic did illustrate the benefits of sound financial backing as well as the sensitivity of the Lake Superior region to the nation market system.

The beginning of the Civil War a few years later had several impacts upon the early development of the iron industry in Michigan, the most important of which was the overall stimulation of the market because of increased demand for iron. Prices for ore rose from \$6.00/ton in 1859 to \$8.50/ton in 1864 (Mansfield 1899:566). Finished iron prices in Pennsylvania were also undergoing marked increases, and at Hopewell Village in southern Berks County, prices rose from \$30.00/ton before the war to \$80.00/ton in 1864 (Walker 1966:64). These nationwide increases helped stimulate production in the Lake Superior mines of the Marquette Range, with ore production increasing from about 69,000 to 280,000 tons over the seven years beginning in 1859 (Mansfield 1899:566). These increases reflected the expansion of mining operations, as well as improvements in the efficiency of ore movement.

Other influences of the Civil War on the iron industry were less tangible but of equal importance to future development. For example, there was a general improvement of opinion regarding Lake Superior iron and iron ore. Before the war, the quality of iron from the range was not widely known and therefore in no great demand. With the greater exposure of the metal to the industrial sector this changed, and Lake Superior region ores proved capable of producing high quality iron.

Another byproduct of the Civil War was the greater exposure of the region as a whole to the "outside" world, especially the usefulness of the Great Lakes for transportation of goods. The war brought about reevaluation when a blockade of the Mississippi forced a change in the routing of goods from the Midwest and central states through the Great Lakes transportation system. The war generally familiarized the commercial sector of the American economy with the true value of the Great Lakes region in terms of transportation and mineral wealth (Hatcher 1950:94).

Following the Civil War, the development of the Lake Superior iron industry continued at a rapid pace. Even though the military demand for iron fell, the direction of America toward industrialization kept the need for the metal at a high level. The railroad industry in particular led in consumption of both charcoal and cast iron. While eastern iron-producing states such as Pennsylvania led in the production of cast iron using anthracite coal and later coke (primarily after 1875), the Upper Peninsula furnaces of Michigan produced only charcoal iron (LaFayette 1977:VIII). This was because there were no other real fuel alternatives within economic reach, since coal could not be shipped north because of deterioration and moisture problems. On the other hand, hardwood was locally available and most early iron companies had highly diversified holdings and controlled large amounts of forest land from which they could extract timber. After 1870, the requirements of shaft mining forced the companies into the logging business in order to supply support timbers for the underground caves. Subsequently, charcoal iron was the only economical alternative left to the companies beyond the option of direct ore shipment.

The type of iron produced with a charcoal fuel was unique because it contained a much lower carbon content than coal or coke iron, making it less brittle. This quality was desirable for many early industrial uses, one of which was railroad wheels. Later, the demand for charcoal iron decreased to such an extent that by the turn of the century, charcoal iron was of little importance.

During the period from the Civil War to around 1880, a number of major changes altered the course of the iron industry. Of greatest overall importance was the shift in philosophy from a mixed pattern of iron production and ore shipment to a full scale program of direct southerly shipment of the raw ore. This change occurred gradually and was accepted by different companies at different points in time. One major reason for the changeover to ore shipment was the increase in expense of local iron production. Although 25 furnaces were built in the Upper Penninsula during the second half of the nineteenth century, almost all failed to make substantial profits as expected (Hatcher 1950: 96). Numerous factors accounted for these failures, but mainly the general expense of charcoal iron. Since it took one acre of hardwood timber (35 cords) to smelt 14 tons of iron, the cost of procuring this resource rose with its increasing scarcity. By the turn of the century, the few furnaces remaining in operation were consuming over 10,000 acres of hardwoods each year (Hatcher 1950:102). As timber stands decreased locally, transportation became a problem and charcoal-producing communities, such as Rock Kilns in Alger County, Michigan, were established along railroad lines to supply established furnaces (Hulse et al. 1977:4-7). Overtime, these increasing costs, combined with lessening demand for charcoal iron, resulted in substantial losses

for many companies and little or no profit for others. But the idea of local production was slow to die and before the last furnace shut down, the Upper Peninsula had produced almost two million tons of iron. Table 2, Appendix A provides a listing of Upper Peninsula forges and furnaces, along with respective production figures.

Even though two million tons of finished iron was of major economic importance to the region, this figure is small in comparison to total regional shipments of bulk ore for the same period. From 1855 to 1930, five Lake Superior basin mining ranges produced over 150 billion tons of ore. Figure 3 illustrates the relative production of the four ranges that transported ore across Lake Superior. Table 3, Appendix A presents annual totals for these ranges.

As this graph illustrates, production rose steadily for all four ranges as did the transportation of ore from the ports of Duluth, Ashland, Marquette, and Two Harbors. The Duluth port in particular showed drastic increases after 1895 and led all other ranges for the remainder of the period.

The discovery and development of these five ranges is of great importance in understanding the output and transportation of ore throughout the Lakes. Before 1877, the Marquette range was the primary production area for the region in terms of both finished iron and iron ore. Later discoveries of ore deposits in Wisconsin and Minnesota changed the picture of the Great Lakes transportation as new railroads were built and different ports developed to move the quantities of ore being mined. Table 3 gives a brief outline of the ranges, their dates of discovery and development, as well as their major ports of shipment.

Figure 3. Iron ore production and transportation for the Lake Superior
Region 1855 - 1930

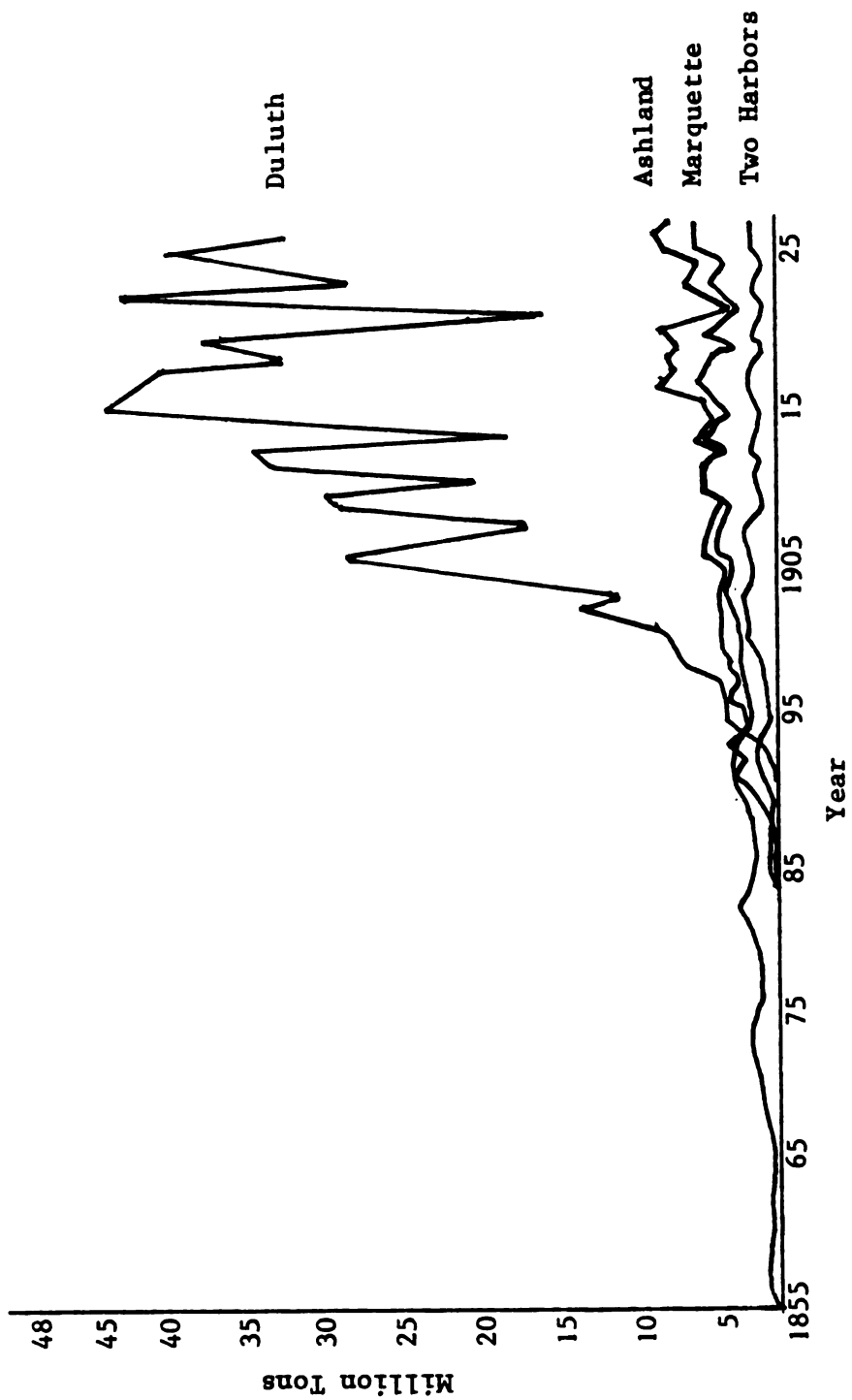


Table 3. Lake Superior Iron Ranges

Range	Discovered	Opened	Port
Marquette	1844	1854	Marquette
Menominee	1866	1877	Escanaba
Vermillion	1875, 1880	1884	Two Harbors
Gogebic	1881	1884	Escanaba, Ashland
Mesaba	1875	1892	Duluth

Sources: (Hatcher 1950:116-163; Bald 1954:278; Mansfield 1899:554-570)

Corresponding Figure 4 illustrates the location of these major iron ranges and the flow of iron to southern ports.

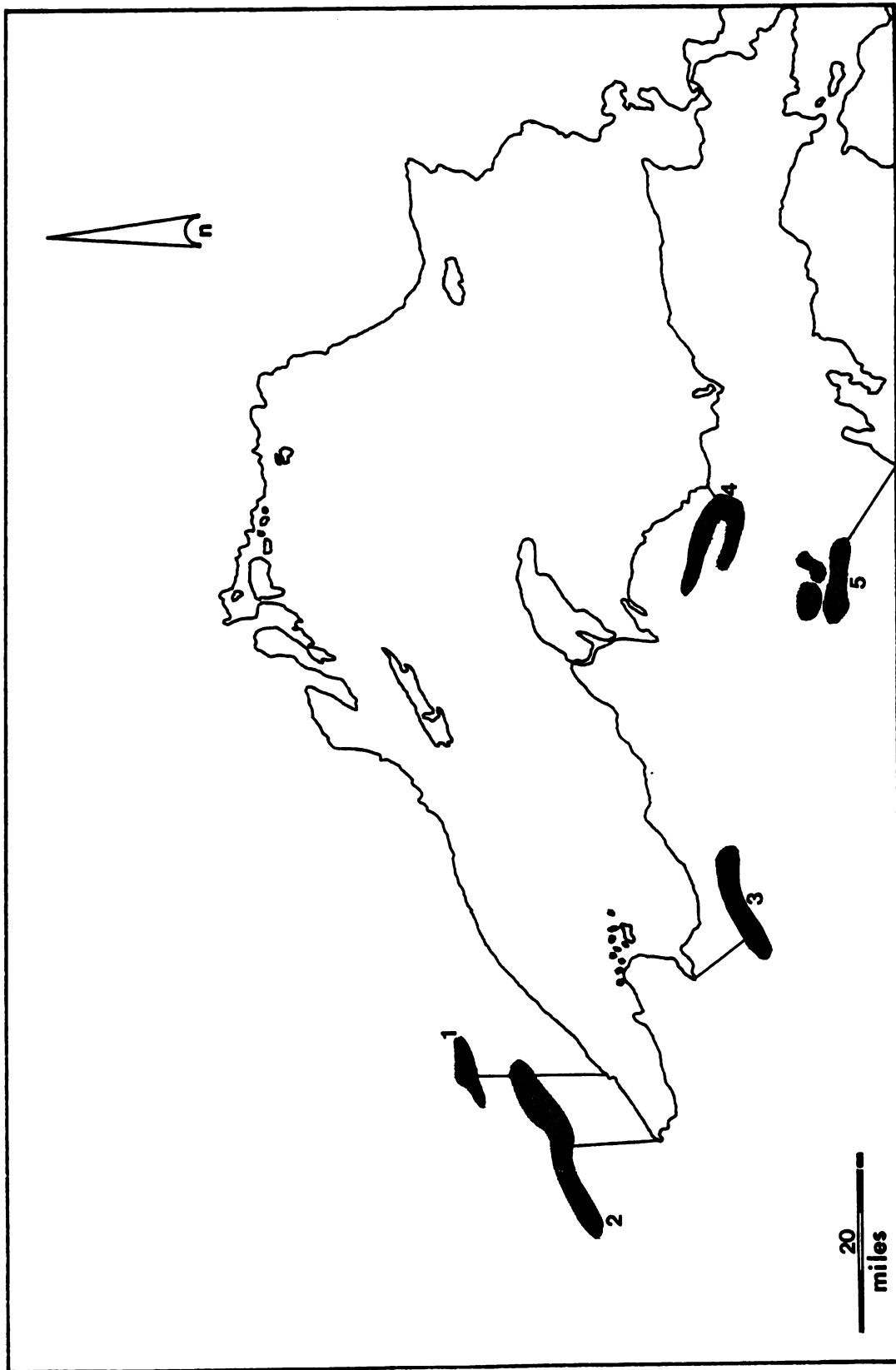
As Table 2, Appendix A demonstrates, there were relatively few furnaces established on the new ranges. Those iron-producing areas begun after the mid-1870s were located away from the ranges on major transportation routes in areas of abundant hardwood forests or port towns with easily accessible timber. This seems to indicate that by 1875, iron production was regarded as a minimally important activity compared to ore shipment.

Expansion of mining operations at each of the five major ranges had a gradual impact on the quality and quantity of ore that was removed from these areas. All iron ore is not the same. Rather, in many cases it is geologically as distinctive as fingerprints on individuals because of the uniqueness of the chemical composition of the ore bearing strata. The composition of ore changed as new areas were opened and as the iron and steel industry developed new technologies for dealing with various types of ore. Before 1870, the Marquette range shipped only "hard" hematite ores; the "soft" ores were not considered to have any value until later (Mansfield 1899:555).

Iron ore as a mineral has a wide range of chemical compositions,

1. Vermillion
2. Mesaba
3. Gogebic
4. Marquette
5. Menominee

Figure 4. Iron range locations



from high grade ores with a large percentage of iron to lean ores with large amounts of jasper, chert, and slate and less than 20 percent of iron (Royce 1938:28). Varying amounts of iron carbonate, silica, iron silicate, aluminum silicate, manganese oxide, magnesium carbonate, iron sulfide, and lime phosphate also comprise most ores. The composition of ore varies markedly within and between ranges and sometimes even within a single mine. In general, there are two broad classes of ores, namely "hard" and "soft." Within each of these classes there are five subdivisions: 1) bessemer, 2) non-bessemer, 3) high phosphorus, 4) manganiferous, and 5) siliceous (Murray 1938:69). Hard ore is dense and breaks into lumps whereas soft ore is earthy and more granular. Bessemer ore classification depends upon the content of phosphorus in the ore: to be regarded as bessemer, the ore can have no more than one percent. Non-bessemer ores therefore have more than this amount and are less desirable (Murray 1938:69). High phosphorus ores contain from .18 to .25 percent phosphorus, and manganiferous and siliceous ores are those containing high percentages of manganese and silica respectively.

In the early years of mining, the ore from a given mine was uniform in chemical composition, but as production increased less desirable ore was shipped. By 1920, the mines shipped several different grades of ore. Because of the need for regularity in the ore at blast furnaces, grading became necessary to assure certain specific compositions of iron and trace elements in a shipment. Too much phosphorus or too little iron would cause problems with the finished iron or steel. The process of sampling ores at the mines, in the boat cargoes, and at the furnaces arose from this need for regularity (Murphy 1938:70-71). Depending on the sample, the ore may be mixed with different

complementary grades to produce a desired composition. Before World War I, grading consisted principally of separating bessemer from non-bessemer ores (Bayer 1938:73). Pricing was based on these grades and only comparatively high-grade ores were traded in the market place. With the advent of specialized steels after World War I, the 10-part grading process became more important (Bayer 1938:73-75). By 1940, the ores removed from the Lake Superior region were so reduced in quality that 40 percent were beneficiated before shipment. Benefication is a process that concentrates ore by crushing, screening, and washing to improve the physical composition (Zapffe and Hunner 1938:77). By the 1960s, this process resulted in the use of taconite pellets almost exclusively as a form of ore shipment.

To summarize the types of ores that were shipped on Lake Superior, Table 4 presents the chronological sequence of development of graded and beneficiated ores.

Table 4. Development of ore shipments

Date	Ore Type
1845-1879	Hard
1860-1870	Hard, Bessemer
1870-1920	Hard, Soft, Bessemer, Non-Bessemer
1920-1940	Graded ores
1940-1960	Graded, Beneficated
1960-present	Graded Taconite

The specific chemical composition of the ores, as well as this general outline of ore shipment, can be used to assign a time period to samples of ore from lost vessels. The availability of assay records is essential to the linkage of ore samples to specific mines, although some

of this information is contained in publications of the Lake Superior Iron Ore Association for various periods.

Transportation improvements in several sectors aided the gradual shift away from local iron production in Michigan's Upper Peninsula. During the early years of experimentation in the iron industry, the only transportation options available to southern ports were through the dock at Marquette. Rail lines connecting the mines of the Marquette range and the dock at the port rapidly boosted production. Likewise, later railroad lines had a similar effect on production in areas that heretofore were inaccessible. For example, the other major ranges were not opened until reached by major railroad routes to such ports as Escanaba (Menominee Range; Chicago and Northwestern Railroad), Ashland (Gogebic; Milwaukee, Lake Shore and Western), Two Harbors (Vermillion; Duluth and Iron Range Railway Co.) and Duluth (Mesabi; Duluth, Missabe and Northern to the Duluth and Winnipeg) (Hickok 1938:16-35). Iron companies and interested investors financed these vital connections for the sole purpose of moving the ore from the fields to the ports for southern shipment. Other minor districts such as the Gunflint and Cuyuna ranges shipped to docks at Port Arthur and Duluth respectively (Hickok 1938: 20, 23).

While railroad systems were developing in Michigan, Wisconsin, and Minnesota, major improvements were also taking place in water transportation. These improvements involved both the advancement of vessel design and technology as well as the improvement of existing waterways to accommodate increasingly larger ships. These changes further defined the advantages of a strategy emphasizing shipment of ore over local production of iron.

Navigation and Industrial Expansion

From the opening of the Sault Canal in 1855 up to the present day, changes in vessel technology have rapidly advanced in the direction of increased size and capacity. In addition, vessel design has been modified over the years to conform with modernization in areas such as loading and unloading technology. The geography of the region has always played a major role in determining the range of vessel types that would be functionally useful to the shipment of ore to southern ports. This is not to say that geography alone has been the single factor affecting vessel design, only that it was a major (if not the major) constraint to development in most cases. For example, the Sault falls constrained development of the Lake Superior region for many years until the first canal system was built. After completion of the canal, the size of the locks affected vessel size in much the same way—i.e., placing limitations on the size of vessels that could pass through the locks. Table 5 lists the construction sequence of the canal network at the Sault, along with the corresponding size limitations of each lock.

Table 5. Expansion of locks at Sault Ste. Marie

Year Opened	Lock Name	Maximum Length	Maximum Width	Maximum Depth
1855		350 ft	70 ft	13 ft
1884	Weitzel	515	80/60 at gates	16
1895	Canadian	900	60	17
1896	Poe	800	100	22
1914	Davis	1,300	80	23.3
1919	Fourth	1,300	80	23.3
1943	MacArthur	800	80	30

Sources: (Bald 1954:245; Nute 1944:136; Hatcher 1950:112-114, 281)

The lock sizes presented in this table should be viewed not in absolute terms because the vessels by necessity have to be considerably smaller

in order to pass the locks. Water depth and vessel draft were major concerns at both the locks and throughout the various passages from Lake Superior to Lake Erie ports.

Navigational improvements occurred at many points in time on the Great Lakes. Regarding depth management, the increasing size of vessels required channel dredging as early as 1855 in the St. Clair flats (Manfield 1899:253). Before 1892, the maximum depth of connecting channels was 16 feet--the same as the Weitzel lock at the Sault. From 1892 to 1897, a major channel improvement program was initiated that created depths of 20 feet throughout the waterway from Superior to Erie. Table 6 provides a brief listing of the major improvements and the dates of completion. Depths before improvement can be viewed as environmental constraints that placed limitations on vessel size.

Table 6. Navigational improvements

Date	Area	Prior Depth	Depth after Improvement
1855-1858	St. Clair Flats	6 ft.	11 ft.
1871	St. Clair Flats	11 ft.	13 ft.
1874-1892	Detroit River/ Lime Kiln	13 ft.	20 ft.
1882-1895	Hay Lake Channel	6 ft.	20-21 ft.
1898	St. Clair Flats	13 ft.	18, 20 ft.

Source (Mansfield 1899:248-253)

When combined, Tables 6 and 9 show that the overall navigable channel depths changed from six feet in 1855, to 11 feet in 1858, to 13 feet in 1871, to 16 feet in 1874, and finally to 20 feet in 1898. This implies that these depths represent constraints on vessel size, and that the accompanying dates provide a sequence of typological expansion. For example, before 1871 the maximum draft of a vessel traveling from Lake

Superior to Lake Erie was under 11 feet. This placed real constraints on the design of vessels and the accompanying tonnage those ships could carry.

A general increase in vessel size for ships engaged in the movement of bulk cargo closely paralleled the sequence of channel depth improvements. The development of vessels for the iron trade has been an ongoing process since the first mines opened in the Upper Peninsula. Generally, before the opening of the Sault Canal in 1855, the small amounts of pig iron and iron ore that were shipped went by schooner, although the screw propeller Vandalia was on Lake Superior by 1841 (Nute 1944:133). Although records for this early period are scarce, few if any vessels engaged in the iron trade were lost during this time. With the opening of the Sault Canal, schooner traffic increased dramatically and was the principal vessel type engaged in the iron trade until the mid-1860s. Beginning in the 1860s, steam barges operated on Lake Superior, making the first inroads in heavy coarse freight. These barges operated in a series of tows by which sail-assisted barges were towed behind the steam tug barge. Older and less efficient sailing craft were soon converted into barges and used in the movement of coarse freight such as iron ore and lumber. This system of tows that proved that the larger the cargo, the less expensive the freight rate. This piece of information influenced the entire course of shipbuilding in succeeding years (Nute 1944:125-126).

In 1869, the first true steam barge, the R.J. Hackett, was built to serve the iron ore trade. This vessel was constructed specifically for carrying ore, with a design that emphasized the bridge in the front and the engines in the rear (Barry 1973:107-109). This ship was a

combination of steam and sail, with the latter serving as an auxiliary power source for open sailing when the winds were favorable. The central portion of the vessel was open for cargo storage, with large hatches spaced 24 feet apart, providing access to the hold for use in the ore pockets at the newly built Marquette docks. Numerous companies built wooden-hulled vessels similar to the R.J. Hackett until the late 1880s when iron-hulled ships were first produced.

Ship builders began producing iron-hulled vessels after the successful service of the Onoko, built in 1882 as a prototype vessel (Bald 1954:279). The Onoko was the first of the iron-hulled bulk freighters and the largest on the lakes at 282 feet in length and a carrying capacity of 2,164 tons. The iron hulls allowed for larger, more stable ships and soon after the Onoko was launched, iron became the material used in hull construction. Because of the peculiarities of the insurance system at the time, the first iron vessels were of composite construction and were iron only from the deck to the water line, with wood below. With the use of iron, bulk freighters were built in numerous styles and evolved gradually toward larger sizes within the constraints imposed by navigation at the locks and channels between Lake Superior and Lake Erie ports. As steel freighters began to be built in 1886, the average size of bulk freighters again increased to just over 300 feet in length, with capacities of 3,400 tons.

By 1906, 600-foot freighters had become the standard workhorses in the Great Lakes iron ore trade (Barry 1973:173). There were several reasons for the replacement of sailing ships with increasingly large bulk freighters. The number of sailing ships, including schooners, barks, and brigs, declined steadily from 1870 to 1890. The main reasons for

this were: 1) size limitations of vessel design, 2) lack of maneuverability in narrow channels, 3) lack of reliability in length of trips from Lake Superior to Lake Erie, and 4) increased cost of wages for sailors working on sailing ships (Barry 1973:143). These four factors made sailing ships uneconomical to operate in comparison with the newer and larger iron vessels in the ore trade.

From 1893 to 1897, a major economic depression bankrupt many of the small iron companies operating in the Great Lakes. The companies that remained solvent through the crisis gained a tremendous competitive advantage and eventually agglomerated into three major corporations—Consolidated Iron Mines, owned by J.D. Rockefeller; Minnesota Iron Company (which became U.S. Steel in 1901), backed by J.P. Morgan; and Oliver Iron Mining Company, owned by Andrew Carnegie and others (Barry 1973:174-177). This consolidation formed large corporations with tremendous financial capabilities and an equally large desire for as large a piece of the market as possible. Economics dictated that it was financially most advantageous for these companies to own their own ore shipping fleets rather than to pay an outside shipper. Eventually this situation resulted in a major period of shipbuilding that lasted through World War I to the next economic downturn in the mid-1920s. During this period, several types of vessels were put into use in the ore trade, among which were the whaleback freighters and the "standard" 600-foot line of bulk carriers. The former were commonplace from the late 1880s to their eventual elimination by 1940. These whalebacks were iron hulled, flat nosed, and similar in appearance to modern submarines. They were eventually supplanted by the larger bulk freighters that could accomodate changes in loading technology and hence more economical to operate (Nute 1944:125).

Table 7 provides a brief summary of vessel types for those ships used in the iron trade.

Table 7. Development of Great Lakes bulk carriers

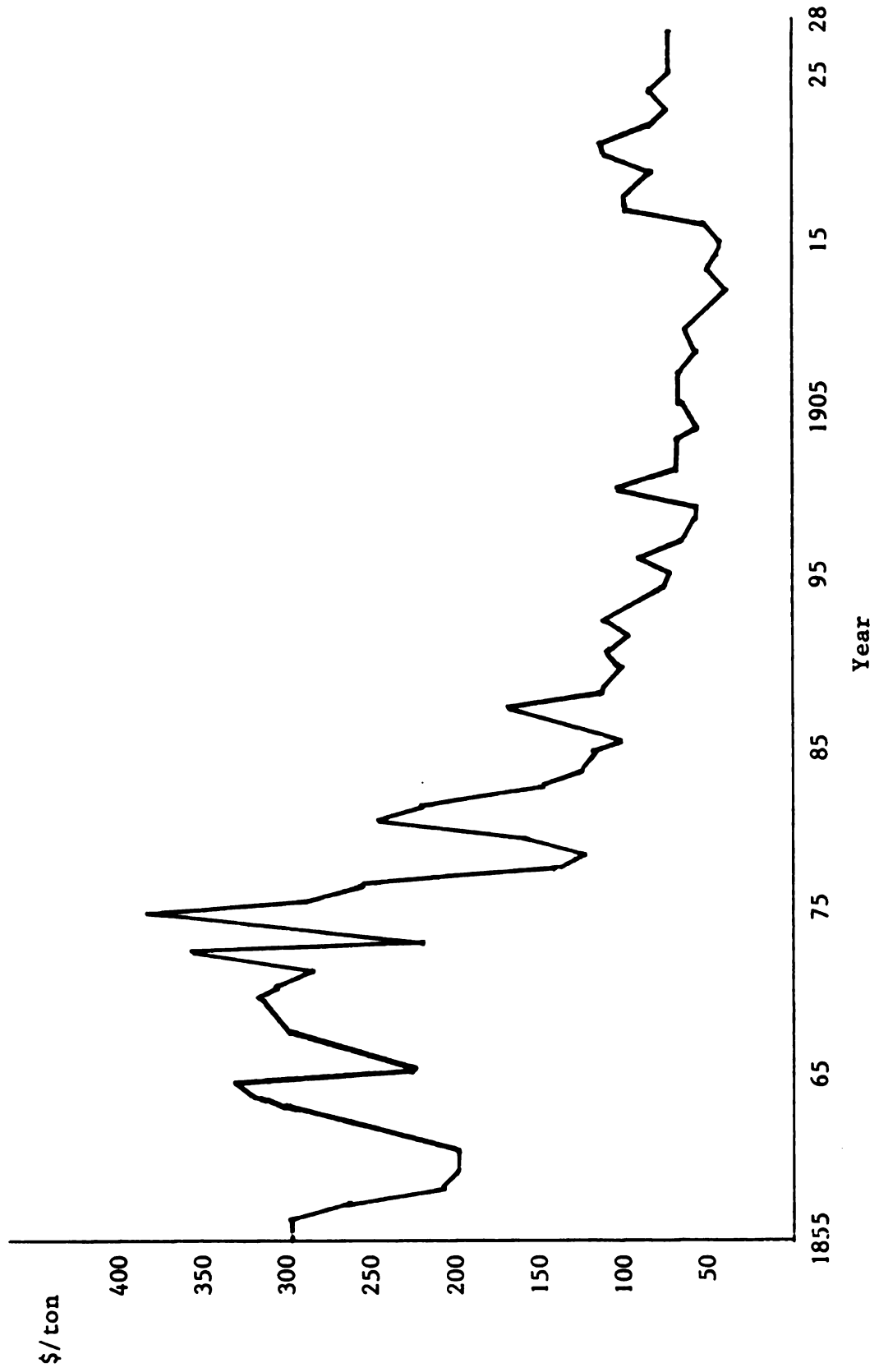
Date	Type	Nominal Length-Ft.	Capacity Long Tons
1855-75	Wooden sailing ships, schooners	200-250	300-700
1860-75	Steam barges, sailing tows		
1870-85	Wooden hulled freighters	210	1,200
1882	Iron-hulled steamer	300	3,000
1888-1930	Whalebacks		
1895	Steel-hulled steamer	400	5,800
1900	Steel-hulled steamer	500	8,200
1907	Steel-hulled steamer	600	12,000
1938	Turbine-powered coal	610	14,000

Source (Erickson 1969:203)

Although this sequence of vessel types is quite simplistic, it shows the general changes through time. Journals such as the Marine Engineering Record should be consulted for the fine details of freighter construction and evolution.

The evolution of larger bulk carriers caused a major reduction in iron ore freight rates from the Lake Superior and Lake Michigan docks to Lake Erie ports. Figure 5 graphically illustrates this rate reduction from 1854 to 1920. The increased capacity of ore-carrying vessels brought about this rate decline. The major effect of this gradual downward shift in rates was to eventually convince the decision makers controlling the iron industry to shift efforts to shipment of ore rather than local production of iron. As Figure 4 illustrates, a major reduction occurred beginning in 1874, the same date as the last major period of furnace building in Michigan's Upper Peninsula (see LaFayette 1977:49).

Figure 5. Freight rates for iron ore 1855-1928, Marquette to Lower Lake
Ports (From Hickok 1938:324)



As the industrial economy of the Great Lakes region expanded, ship traffic on the lakes increased at phenomenal rates. In order to control the flow of traffic as well as to promote safe navigation on the lakes, the federal government was constantly involved in the development of the Great Lakes transportation system. The Lighthouse Service, established in 1789, was one governmental organization dedicated to the improvement of navigation on all the nation's coastlines, including the Great Lakes. This service became involved on the lakes in approximately 1820 when the first lights were established at Presque Isle and Buffalo (O'Brien 1976:13). The earliest lights were built on the lower lakes and as traffic expanded into the upper lakes, the lights soon followed. Lake Superior, for example, was without lights until 1847--only a few years after the iron and copper industries began mining operations in the area. The lights established across the lakes were placed at strategic points to outline hazards or to mark common navigational points such as harbor and river mouths or points of course change. For further information on the history of specific lights, see O'Brien (1976) and Holland (1972).

In 1876, the Lifesaving Service also began operating on the Great Lakes. The Great Lakes became the ninth, tenth and eleventh districts within the national system, and headquarters were established at numerous points along the Lakes to provide a rescue team for ships in distress. This service was responsible for thousands of rescues, as was the organization it later became--the U.S. Coast Guard.

A major area of governmental concern during the development of the Lake transportation system was directed toward the creation and improvement of harbors. Numerous congressional appropriations were

were approved for this task, with the goal of reducing vessel loss through the availability of refuge harbors (Mansfield 1899:263-264). Table 8 provides a list of harbors on the upper lakes as well as dates of improvement, if any. This listing covers only those improvements before 1900 (Mansfield 1899:315-364).

Table 8. Harbors of Lake Superior

Port	Date	Navigable Depth-Feet
Sault Ste. Marie		
White Fish Point		
Grand Marais, MI	1881-1898	13
Munising		
Marquette	1867-1898	18-40
L'Anse		
Copper Harbor		
Eagle Harbor	1879	14
Ontonagon	1867-1898	12
Ashland	1886-1898	16
La Pointe		
Bayfield		
Portwing		
Duluth	1871-1898	16
Superior	1867-1898	16
Two Harbors	1889-1898	good navigable depth
Grand Marais, MN	1880-1898	

Just as the depth of navigable waterways was of great importance to the development of lake vessels, so also was the size and depth of harbors--especially those used as primary loading and unloading docks. The dates of harbor improvements closely parallel the development of the various regional industries, and many harbors had ongoing programs of expansion in order to maintain facilities for increasingly larger vessels (Mansfield 1899:354-362). Harbor improvements included the dredging of harbors, the building of breakwaters and dock systems, and the cutting of channels into nearby smaller lakes. Although many harbors underwent some type of improvement, most were not suitable for

use as harbors of refuge because of their unprotected nature. Only those harbors that could provide safety in storms were recognized as refuges, and these were extremely scarce on the lakes before massive breakwaters became commonplace. Additionally, the gradual expansion of vessel size made only certain harbors available for use either as normal harbors or refuges. Depth and size of harbors were again the major constraining features for large vessels used in bulk ore shipment. Therefore, a large vessel in distress was severely limited as to which harbor could be sought without fear of running aground.

At the major ports handling the shipment of iron ore, numerous changes took place in both harbor improvements and technological innovations in dock technology. Techniques of unloading, for example, kept pace with the evolution of lake vessels, whereas loading and unloading took place with ore in barrels and then later in bulk by shovels and wheelbarrows. The invention of the clamshell bucket just before the Civil War greatly reduced the time and costs of ore transfer (Hatcher 1950:114-115). Later improvements involved the construction of railroad trestles and docks so that vessels could be loaded directly from mine cars. These improvements have resulted in a gradual reduction in the length of time needed for the loading and unloading process. At the turn of the century, the average turnaround time per 1000 tons of cargo was 331 minutes. By 1950, this time had been reduced to 37 minutes (Hatcher 1950:217). In terms of average total loading time, the length of stay at the dock decreased from 52.5 hours in 1900 to 5.6 hours in 1950 (Hatcher 1950:217).

The overall effect of technological improvements in vessel design and dock facilities was to increase the number of round trips

that vessels could make in a season. In addition, for approximately the same period, there was a phenomenal rise in total tonnage on the lakes but only a slight or moderate increase in the average number of working vessels (Wolff 1972:62-63). The combination of technological improvements in docking and in increased size led to an overall gradual reduction in the number of vessels working the lakes. This was especially true in the iron industry with the evolution of bulk ore carriers after the Civil War.

The Grain Trade

The Great Lakes grain trade is comprised of numerous agricultural commodities that are often treated as a single commodity--grain. But in reality, raw products like wheat, corn, oats, barley, rye, and processed cereals and flours are each separate entities with special considerations. They are grown and processed in different regions at different points in time and have particular qualities that affect their preservation and transportation, making each commodity unique. Traffic in these different grains centers on various markets across the Midwest, with each marketplace dealing in varying amounts of certain grains.

In the Lake Superior region and surrounding hinterlands, wheat has historically been the dominant commodity, with near exclusion of the other types of grains. Since the 1870s, wheat has comprised a large majority of the total grain traffic on Lake Superior (Williamson 1977). This dominance of wheat is a result of the environmental conditions present in the region as well as the frontier atmosphere that permeated the region into the 1930s.

During the period between the opening of the St. Mary's Ship Canal and the early 1870s, the Lake Superior region underwent a process

of settlement and development in all sectors of the economy. The emerging industries such as iron, copper, and lumber rapidly settled the region. This early period also saw experimentation in agriculture in Michigan, Wisconsin, and Minnesota, with special emphasis on wheat production. The flow of grains before 1870 moved in an upbound route with wheat and flour coming from southern and eastern areas to meet the food demands of the developing region (Mansfield 1899:526). Ships would stop at each of the accessible ports with cargoes of flour and whole grains (for animal feed) and then return to the south with varying loads of freight.

The early 1870s mark a turning point in the grain trade and the emergence of a new pattern of commerce on the upper lakes and Lake Superior region (Odle 1953d:260). Before this time, the center of the national grain trade was in the north central region of the country, with the Great Lakes forming the north and east boundaries and the Mississippi and Ohio rivers forming the south and west borders respectively. The eastern transportation route to the New England and Middle Atlantic states opened upon the completion of the Erie Canal in 1825, and grain found its way from Midwestern farming centers along this route. Later, canal networks such as the Ohio and Erie, Miami and Erie, Wabash and Erie, and Illinois and Michigan opened up this eastern route to interior agricultural areas (Odle 1951:238-239). Cleveland, Toledo, Detroit, Chicago, and Milwaukee became the major market centers for this early trade.

At this same time, Midwest grain products were also moving south by way of the Mississippi River system. Like the east, the southern portion of the country before the Civil War could not feed itself

without importing food stuffs from other regions. The flow of grain from the southern portion of the east North Central region was accomplished through St. Louis and Cincinnati markets. From there, grain moved south to New Orleans and on to Southern Atlantic states (Odle 1951:245). In the 1850s, some of this Mississippi River trade was diverted through the eastern Great Lakes route because of the settlement of northern Great Lakes states and the commercial revolution brought about by the development of the railroad and telegraph (Odle 1951:244).

By 1850, a westward shift in the grain trade was underway and Toledo, Chicago, and Milwaukee became the focus points of the market as Cleveland had been in earlier years (Odle 1952a:24). The decades of the 50s, 60s, and 70s were especially important to the grain trade because during these years, the centers of flour and grain marketing underwent rapid change largely because of improved transportation and communication between the West and East. The telegraph, for example, facilitated direct purchases of western commodities by eastern buyers. Transportation by newly developed water and railway systems allowed for the reliable movement of grain commodities to eastern centers, thus bypassing the middlemen. Before the 1850s, most grain was funnelled into Buffalo and from there, distributed to the East. The railroad and telegraph allowed Buffalo to be circumvented, the individual eastern marketplaces could directly purchase western grains (Odle 1953b:108). Ultimately, this resulted in a westward shift of grain and flour markets.

During the Civil War, railroads successfully competed with water transportation for the first time. Normally, railroad movement of grain was reserved for winter transportation when the water routes

were closed for the season. The need for foodstuffs for the Union war effort necessitated the rapid deployment of grain and flour by rail routes. After the war, the "normal" system of grain movement was resumed and water transportation remained immensely more economical than rail transport for most agricultural commodities. This was not the same for the movement of flour, which continued to be transported by rail even after the war ended. Flour was the first commodity of comparatively low value the railroad carried that could successfully compete with water transportation. Several factors accounted for this success, including the difficulty of transshipment and the need for rapid movement of this perishable commodity. In addition, flour could not be stored over the winter months without considerable loss, so railways were the only alternative to transportation for flour made from the fall harvest (Mansfield 1899:530).

In the Lake Superior region, the grain market was not well-developed before the early 1870s. The movement of markets in a westward direction, combined with western land settlement, eventually led to the opening of the Lake Superior region to traffic in wheat and other grains. The wheat that traveled on Lake Superior came from two major sources--one American and the other Canadian. The American grain trade on the lake began with the production of wheat in northern Minnesota and eventually moved to encompass portions of the Dakotas (Odle 1953d:260). Wheat produced to the south of this area found its way through Lake Michigan ports, such as Milwaukee and Chicago, and did not have to travel across Lake Superior.

The first wheat produced in Minnesota in the 1850s was shipped south to St. Louis by the Mississippi route and east to New York

through ports such as Milwaukee (Jarchow 1948:4-5). This pattern remained the same until the Civil War, when the Milwaukee port gained major control of the market. Despite competition from Chicago, Milwaukee retained the major share of Minnesota wheat traffic until the 1880s.

In September 1870, the grain trade on Lake Superior began with a railroad connection from St. Paul to Duluth, thus opening the traffic of the inland areas to the northern water route across the lake. In the fall of 1871, the influence of Duluth as a shipping port was further enhanced when the St. Paul and Pacific Railroad reached the town of Breckenridge in the upper Red River Valley, and the Northern Pacific Railroad secured a connection between Duluth and Moorehead (Jarchow 1948:13). This latter route was completed to Portland, Oregon, in 1883 (Garraty 1971:75). These railroads tremendously increased settlement and agriculture in the routes, all of which were channeled through Duluth. In the 10 year period from 1870 to 1880, wheat production doubled with much of this increase coming from the newly opened lands (Jarchow 1948:16).

Wheat production was not limited to Minnesota, but began a general westward movement along transportation lines. Wheat adapted well as a frontier crop because of its relatively low operating expense per return. With large amounts of inexpensive land available in frontier areas, the problems of declining fertility were of no great consequence. But as the land became more settled and prices of farm land rose, wheat became less and less profitable in relation to other crops or land uses. For this reason, wheat has historically followed the westward settlement as a frontier phenomena (Jarchow 1948:27). Thus,

the movement of wheat areas first from southern Minnesota to the north and eventually into the Dakotas and westward can be explained in part by this concept of changing rent values. Nonetheless, the importance of expanding wheat-growing areas to the Lake Superior grain trade remains because Duluth became the single terminus point on the lake from which these commodities were shipped.

The American grain trade on Lake Superior was not completely restricted to wheat, although this was by far the major grain. Wheat flour can also be regarded as a major part of this overall commodity. Flour milling, like wheat production, also had its major beginning in the state of Minnesota. Minneapolis became the center for this production and throughout the period, lead in flour production for the Lake Superior trade.

Before 1873, the flour produced in the region was of relatively low quality and brought prices commensurate with its position. The major problem with the flour quality lay in both the varieties of wheat being processed and also the technology used in flour production. Because the climate of northern Minnesota and the Dakotas were too severe for the existing winter wheat varieties, spring wheat was the primary type grown in the region. The hard, red spring wheats were well-adapted to the cold climate, but the bran of this type of wheat shattered during the milling process and imparted an undesirable orange tint to the flour (Olde 1953d:260). The technology of flour production consisted of grinding the wheat between rapidly spinning millstones so that as much flour as possible could be made at the first grinding. When this process was used, it did not fully succeed in separating the various components of the wheat berry. And as a result, the bran

discolored the flour and the flour sometimes became rancid from excess oil in the germ. In addition, the process often sifted the gluten cells out of the flour, which adversely affected its baking quality.

When spring wheat was milled, these problems became more exaggerated and a very low quality flour was produced (MacGibbon 1932:402). Winter wheat flour was whiter, stronger, and had better keeping qualities than spring wheat flour, and therefore it commanded a premium price.

In the early 1870s, Minneapolis millers imported a European technique of refining that eliminated the specks of bran while preserving the high gluten content of the wheat. This technique, called the middlings purifier, allowed for the deporation of the bran before grinding. A system of slow grinding first cracked the wheat. Then the remaining berry (middling) was purified from the bran and ground into a pure white flour (MacGibbon 1932:403). The resulting new "patent" flour established a large market for hard spring wheat. Wheat processed with the middlings purifier was immediately more desirable, and prices tripled immediately (Jachow 1948:16; Odle 1953d:260-261). This in turn stimulated more spring wheat production, and encouraged further expansion of the frontier region.

Other technological innovations of major import to the milling industry included the adoption of the metallic roller process of grinding and the centrifugal reel for sifting (MacGibbon 1932:403). These innovations continued to enhance the quality of flour produced and strengthened the financial base of both the American and Canadian flour and wheat industries.

With all the wheat and flour of the north central region passing through the ports of Duluth and Superior, large grain-handling facilities quickly developed. From the 1870s on, grain elevators, storage warehouses, and loading technology expanded in tune with production. Because of the seasonal nature of the wheat crop, storage facilities were an essential element of the grain trade, and by the turn of the century, there were 18 major elevators at Duluth/Superior with a capacity of 25 million bushels (Mansfield 1899:536). Wheat began to ripen in early and mid-August and continued into November, depending on local conditions (Jachow 1948:21). Grain and new flour traffic on Lake Superior was heaviest during these last months of navigation before winter. Since flour could not readily be stored over the winter that which did not leave port in the fall was shipped by rail during the winter months. Upon spring re-opening of the Lakes, wheat was one of the first commodities moved and in the months of April and May, grain traffic was quite heavy while flour traffic was slight to nonexistent.

In contrast to grain, which was transported by bulk carrier, wheat flour was usually shipped in barrels, and therefore often transported by package freighters or vessels carrying mixed cargoes. Package freighters often made extra stops along a route to pick up or drop off cargo, and the trade routes of these vessels were different from bulk carriers, with only a single destination.

The second major component of the Lake Superior grain trade was the Canadian system of production and transportation. This Canadian grain industry evolved along separate but parallel lines and was closely linked throughout with changes in American markets and policies. In Canada as well as the U.S., the pattern of wheat agriculture that

followed frontier expansion was the same (MacGibbon 1932:3-16). Farming in Ontario and eastern provinces began during the French Regime but did not reach high rates of production until the nineteenth century. Stimulated by increased demands for exports during the Crimean War (1853-1856) and the American Civil War, wheat farming in Ontario and Lower Canada rose sharply (MacGibbon 1932:17).

During the pre-1847 period of grain production, Canada shipped nearly all its grain through Montreal for export to Europe. It exported very little grain, if any, into the U.S. either for consumption or transportation. After 1847, political agreements between Canada and the U.S. resulted in the opening of transportation networks previously restricted to sole use by each respective nation. A rapid change in Canadian grain shipments accompanied this agreement, and large amounts of wheat and other products were exported from Upper Canada through American seaports on the Atlantic (MacGibbon 1932:18).

As Canada became more densely settled, the wheat farming areas began to shift to the west into the provinces of Manitoba and Saskatchewan. Although farming was attempted in these areas throughout the nineteenth century, it was not until the 1870s that wheat production became of any great importance. This was because of the lack of efficient transportation systems to move grain eastward. After Duluth secured its railroad connections in 1870 and 1871, grain from Canada moved by inland waterways to junctions on the American route to the East. From Duluth, Canadian wheat made its way across Lake Superior, through the St. Mary's Canal to Canadian ports on the Georgian Bay, and then eastward by rail. Preceding 1883, grain from Manitoba was channeled through Duluth and across the same routes as Minnesota and

Dakota grain (MacGibbon 1932:26-28).

A major grain transportation revolution occurred with the completion of the Canadian Pacific Railroad in 1883. This railway connected Winnipeg and Port Arthur, giving access to a Canadian port on Lake Superior. Although hindered by financial difficulties in early years, the Canadian Pacific was eventually completed to the west coast in 1885 (Royal Grain Commission 1938:18). This railway opened fertile western lands and wheat agriculture closely followed settlement in these western regions. Wheat production steadily increased in the Canadian west as settlement and transportation became widespread. The Great Northern (1889), Northern Pacific, and Grand Trunk Pacific railroads supplied the means for the movement of immigrants, goods, and pioneer wheat from these western areas (Royal Grain Commission 1938:16-20). During 1883 to 1920, the twin cities of Port Arthur and Fort William constituted the major grain shipping centers for the entire western Canadian grain trade.

The opening of the Panama Canal in 1914 caused far-reaching changes in the flow of ocean traffic, including the world movement of grain. Farmers in Alberta and western Saskatchewan now had an alternative route for their exports (MacGibbon 1932:266). Despite a delay caused by World War I, by 1920 there was a diversion of western grain away from the eastern Great Lakes route to a Pacific route leading through Vancouver, British Columbia. Lack of grain-handling technology at Vancouver and initial resistance from the railroads made growth slow but steady throughout the 1920s.

The Canadian milling industry grew along lines parallel with American flour production. Technological innovations introduced into

Minneapolis soon found their way into Canada and had similar successes. In Canada, milling became a major activity in several towns along the route from the western prairies to the eastern seaboard. Along the Canadian Pacific Railroad, the towns of Winnipeg and Keewatin (130 miles to the east) became major milling centers for western grain (MacGibbon 1932:404). Flour would then be shipped eastward to Duluth and across Lake Superior or would travel an all-rail route through one of numerous connections east.

Other milling centers include Montreal and Port Colbourne, the latter serving as the entrance port of the Welland Canal at the eastern end of Lake Erie. Lesser areas of flour production also include the towns of Goderich and Fort William (MacGibbon 1932:405). Transportation of flour produced at Fort William was also shipped on Lake Superior following a southerly course to Sault Ste. Marie.

The Coal Trade

The coal trade on the upper Great Lakes differed greatly from the other commodities moved in this region primarily because coal was an upbound cargo moving from Lake Erie ports northward rather than southward, as did the other cargo types. Another major difference lies in the distribution of coal along this northerly route. Unlike ore, grain, and lumber, which were produced in an area and shipped to another specific area, coal was produced and shipped to a much wider variety of destinations. Rather than a raw material that was processed in one central location, coal was a fuel source that needed no further processing. As the need for fuel grew with expanding population and industry, greater amounts of coal were shipped into the northern lakes.

And as new settlements grew and exhausted the timber resources of the surrounding countryside, coal became more economical and trade routes to these towns sprang up.

Coal had many uses for the Lake Superior region as its population expanded. From their earliest beginnings, for example, the mining industries were highly dependent upon steam power. The transportation industries of shipping and railroads also needed coal for steam power, and with the railroad boom in the late 1880s and 1890s, demand for coal sharply increased. The railroad industry was especially dependent upon coal since steam powered vessels could not afford to carry bulky wood fuel on board. A steamship traveling from Lake Erie to Duluth had to carry enough coal for both upbound and downbound legs of the journey. So much of the coal that passed through the Sault Canal never touched land because it was consumed by the vessel throughout the course of travel (Williamson 1977:186).

Other coal destined for population centers was deposited at the major ports along Lake Superior (Williamson 1977:179). In fact, because of the region's settlement pattern, these lake ports remained the only major population centers for the entire 1855 to 1930 period. Those major ports and their dates of settlement are listed in Table 9.

Table 9. Lake Superior ports

Name of Port	Settled	Major Development Period
Grand Marais, MI	1860s	1860 - 1910
Munising, MI	1867	1867 - 1920
Marquette, MI	1845	1857 - present
Houghton, MI	1852	1873 - 1930
Ontonagon, MI	1852	1855 - 1900
Ashland, WI	1850s	1877 - present
Duluth/Superior, MN	1850s	1871 - present
Two Harbors, MN	1884	1884 - present
Port Arthur/Ft. William, ONT	1884-92	1884 - present

Although numerous other small ports were scattered along the Lake Superior coastline, they most likely received few if any shipments of coal.

Because of the numerous destinations of coal-carrying vessels, the trade routes these vessels traveled were quite different from those of the other bulk cargo carriers. The vessels carrying coal often made several stops before emptying the cargo hold of a vessel. For example, a vessel might make stops at Grand Marais and Munising before finally unloading at Marquette. This diversity in destinations meant that the vessels carrying coal were also more diversified than grain and/or ore vessels. Smaller vessels were needed to enter the shallower ports, and some coal destined for smaller ports was carried on vessels that accommodated mixed or package freight. Therefore, coal was not handled specifically by bulk carriers that left those ports with ore or grain. Upbound, these big carriers more often than not carried coal cargoes to increase the economic utility of the vessels. The large majority (probably 80 percent) of coal brought into Lake Superior was destined for the major ports of Marquette, Duluth, Ashland, and Houghton. Initially, the coal was used primarily at those locations, but as the railroads connected ports to interior areas, increased amounts of coal were shipped out from these ports to the outlying areas. Thus, there was a gradual change in the role of these towns from consuming points to both consuming and distribution points. This was especially true for Duluth, which acted as the center for almost all coal destined for the northeast (Mansfield 1899;551). Table 14 lists the amounts of coal that came into Lake Superior for the period 1855 to 1920. This table shows that the major shipments of coal to the region began during the

late 1870s. This corresponds with the time of major development in the region, most notably the railroad era.

Historical Summary and Comparisons

The iron, grain, and coal distribution networks on Lake Superior were similar in some respects and different in others. The major similarities between these three commodities lie with the bulk nature of the cargoes. Iron ore, grains of all types (excluding flour), and coal were all loaded in bulk into vessels specifically designed to carry these types of commodities. The cost of transportation for all three commodities was dependent upon the amount of cargo moved in a single voyage. The general types and sizes of vessels employed in these trades would therefore be more similar to each other than they would be to vessels moving other types of commodities. But this is where the similarity ends and major factors distinguish the vessels of each commodity trade from one another.

Trade routes are a function of three factors: 1) point of origin, 2) point of destination, and 3) geographic space across which movement takes place. These factors were significantly different for each industry. The location of iron deposits and their chronological differences in discovery and development contributed to a pattern of ore shipment distinctive to the iron industry. The ports of Marquette (1855), Ashland (1884), Two Harbors (1884), and Duluth (1892) became the points of origin for tremendous quantities of iron ore. The routes between those ports and Sault Ste. Marie were different from grain or coal routes. Grain, for example, was not shipped on Lake Superior before 1870 and only two major routes, Duluth (1871) and Port Arthur (1884), were utilized for grain shipments. Compared to iron,

these chronological and spatial differences were quite significant, the one exception being shipments from Duluth for the period 1892 to 1920, when both used identical routes.

The coal trade is poorly documented in comparison to either grain or iron industries, so comparisons must be made with extreme caution. Since coal was often used as an upbound return cargo, the routes traveled would be similar to a combination of the routes of both the iron and grain trades, but would be dissimilar to either when viewed separately. In addition, the destinations of some coal vessels would not necessarily be to the same port or ports from which the downbound voyage was made. Smaller ports having dock facilities that could accommodate bulk carriers would act as secondary distribution points for the hinterland. Therefore, routes of coal delivery could require a larger number of stops per trip and would entail deliveries at a larger variety of port towns. Resulting patterns of coal trade distribution systems would be significantly different from either iron or grain patterns. The development of coal traffic on Lake Superior was closely linked to the economic and demographic development of the region. The trade routes that coal followed would therefore parallel the movement of industry and the settlement of large populations, as discussed previously in this chapter.

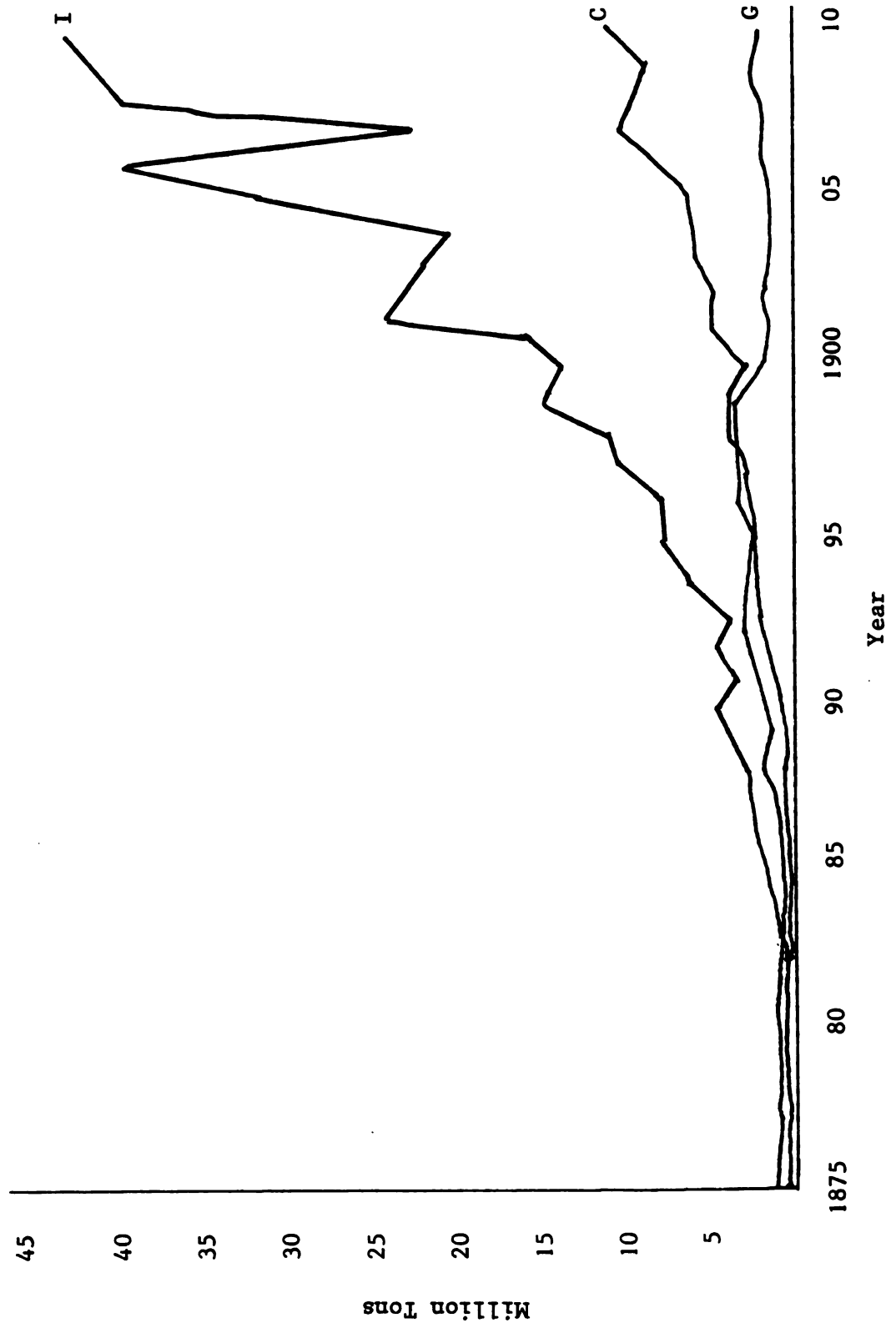
Along with differences in trade routes, a host of factors had an effect on shipping, including: 1) the relative distance of each route; 2) the presence or absence of navigational hazards, constricted passages, or course change areas; and 3) the weather patterns that may affect one part of the lake differently from another. Each of these three elements combine to intensify differences between routes. When

it is pointed out that iron ore routes are different from grain routes, the implication is that each industry will be faced with different selective pressures.

Differences between iron, grain, and coal extend beyond routes of trade and chronological development and into more specific types of characteristics. The relative frequency of traffic, for example, is an important factor in distinguishing between the three commodity trades. Since vessel types and sizes were comparable among the industries under consideration, the frequency of traffic of each commodity would be a function of the relative amounts of that cargo being moved on the lake, as shown in Figure 6. Assuming that ore vessels and grain vessels are the same size and type, then if one million tons of iron ore was moved in a given period compared to a half million tons of grain for that same period, the frequency of traffic for ore would be double that of grain. That is, twice as many trips would have been made by ore vessels than by grain carriers. Since this is potentially important to understanding vessel loss, the production figures previously listed in this chapter assume an important role in determining the relative frequencies of traffic between the three types of commodities.

When reviewing differences between the three commodities, it is also necessary to examine the nature of the base industries that controlled the production and shipment of these cargoes. For example, the iron industry was highly centralized and developed with controls over both mineral extraction and refining systems. It was a type of industry that had tremendous capital at its disposal and could therefore afford the newest technology available. As vessels became larger and more cost efficient, the iron industry invested heavily in these newer

Figure 6. Iron, grain, and coal tonnage on Lake Superior 1875-1910



vessels. So it is likely that ore-carrying vessels were more modern (i.e., larger) than other less centralized industries. In comparison, the grain trade was more a conglomeration of smaller, agriculturally based distributors less likely to act as a collective whole where capital improvements were concerned. Vessels of the grain trade were independently owned and operated as opposed to iron industry vessels that were predominately (especially in the later periods) company owned. The same could be said for those vessels involved in the coal trade, except those in iron company fleets. The disparity in capital inputs between the iron industry and other commodity trades is great and would be reflected in the types and sizes of vessels in the respective industries.

The nature of the cargoes is another factor that results in differences between vessels of each industry. Iron ore, coal, and grain have different qualities that affect how each is handled and transported. Iron ore is impervious to water, whereas coal absorbs water, which reduces quality and utility. On the other hand, grain is often totally destroyed by water or is at the least rendered unfit for human consumption. The relative densities and bulk of these goods may also have an effect on the likelihood of cargoes shifting in the holds of vessels although the specifics of this are not currently known. Thus, the characteristics of the cargoes themselves may have been an important factor in their shipping or salvage.

The seasonality of the various cargoes would also have created differences between the movement and distribution of the three commodities. Grain, for example, matures from mid-August to November and was predominantly a fall crop. The need to move this grain before the close

of navigation caused a surge of traffic of this cargo late in the season. This situation was somewhat alleviated by the construction of elevators that could store grain over winter months. Yet the traffic remained heavy in the fall months, while a second surge was occasioned by the opening of spring navigation and the need to quickly clear elevators before spoilage occurred. This seasonality contrasts with the iron and coal industries, which maintained steady shipments throughout the season. Coal traffic may have been slightly heavier in the fall months because of a desire to stockpile fuel for the region's long winters.

This comparison between the iron, grain, and coal industries serves to briefly outline their major differences as seen in the industrial histories of the three commodity trades. These differences have an impact on a wide array of factors--the relationships between which are not currently understood. From this historical sketch, a number of elements appear of potential interest to the question of representativeness. These factors are:

- 1) trade route locations
- 2) geographic variations along trade routes
- 3) commodity types (cargoes) transported
- 4) chronological development
- 5) vessel type and size
- 6) susceptibility to loss
- 7) ports of origin and destination
- 8) frequency of traffic
- 9) periodicity of navigational season

In the following chapter, these elements and others will be utilized to form hypotheses about the relationship between the development of the shipping industry and the resulting shipwrecks. The model presented will order these variables into a cohesive framework for study and will suggest relationships between variables based on the historical information discussed thus far.

CHAPTER IV

THE FORMATIVE PROCESS

This chapter organizes the historical information from the preceding chapters into a format that illustrates the interrelationships between shipping and the formation of the shipwreck archaeological record. The structure of the shipping industry was a result of numerous factors linked to industrial expansion and development in several major industries. Such factors as the physical environment, chronology of development, degree of capital inputs in vessel technology, and the seasonality of shipping conditioned the transportation of iron, grain, and coal.

In regard to shipping, each of these commodities was structured slightly differently because of their individual organization and characteristics. Therefore, Lake Superior shipwrecks should reflect the shipping industry as a whole as well as the specific commodities that were transported across the region.

The shipping industry was a dynamic, constantly changing system. As outside demand for commodities rose, so did vessel traffic. And as economic decisions were made by individual industries or companies, the composition of the vessel fleets in service on the lakes changed accordingly. Theoretically, this process of change and development should be reflected in the frequencies and types of shipwrecks that occurred. As previously stated, the goals of this study are to search

for spatial regularities in the distribution of shipwrecks and to provide explanations for wreck patterning, if it is found to exist. This can be accomplished in part through an understanding of the process by which the shipwreck archaeological record was formed.

The formative process of the archaeological record is relevant in several ways to the investigation of spatial distributions. First, in order to recognize spatial patterning of shipwrecks, it is necessary to know and understand the patterning of the cultural context which produced them. The shipping industry as a whole was structured in several ways because of chronological development, trade routes, and economic demand. Likewise, weather patterns, fog zones, and areas of restricted navigation structured the physical environment. Both factors had a major effect on the extent and development of the shipping industry on Lake Superior.

Within the constraints imposed by the cultural and natural environments, the shipping industry developed into a major transportation network responsible for the movement of large amounts of commodities and people across the region. The iron, grain, and coal trades that serve as the focus for this study were each affected a bit differently during their development. For example, the iron industry had an earlier period of development and had a more extensive movement of cargo across the lake. In addition, the financial resources of the iron industry were more substantial than either the grain or coal trades because of investment by wealthy eastern backers and later by huge multi-national companies such as U.S. Steel. This allowed for more capital improvements in terms of larger and more modern vessels; the iron industry fleets were the most extensive in the Great Lakes region. This cultural context

provides a setting for the shipwrecks in the iron, coal, and grain trades. This economic system, which serves as a backdrop for the study of Lake Superior shipwrecks, has been referred to as the "systemic context" by Schiffer (1972) and others (Reid, Schiffer, Neff 1975:210). In contrast, the actual archaeological record (such as shipwrecks) is referred to as the "archaeological context." These concepts are useful not for the jargon they introduce but for the idea that there is a process of transformation that takes place between these two contexts. The formative process of the archaeological record is the means by which the "systemic context" (the shipping industry on Lake Superior) is changed into the "archaeological context" (Lake Superior shipwrecks). An understanding of any aspect of archaeological sites depends on the knowledge of this formative process. In this study, it is useful to point out that shipwrecks offer an opportunity for an elaboration of this process because of the type of data available for study. The cultural and environmental variables that affect wreck deposition are of two types: 1) those variables contributing to loss; and 2) those relating to the eventual decomposition of wrecks underwater. The present condition of the archaeological record is therefore a result of these two separate types of factors, which Schiffer (1972) has termed "transforms." But Schiffer fails to differentiate between factors that affect the initial deposition of a cultural phenomenon and those that affect the extent to which decomposition takes place. For the purpose of this study, these can be termed depositional transforms (Type A) and archaeological transforms (Type B).

Type A variables are those factors that aid in the deposition of cultural remains, while Type B variables relate to those factors that

aid either the preservation or decomposition of those remains. For example, once an artifact is produced there are numerous factors that influence how it is used and how it is eventually deposited in situ (Type A variables). Some of those factors are cultural, such as the economic system which dictates how that object will be used, while others are noncultural, like the natural environment. Through a combination of factors, that object is eventually removed from the cultural system either through intent or through loss. When the object is deposited, it becomes a potential contributor to the archaeological record. And the moment that deposition occurs, the artifact begins the process of decomposition. At this point, Type B variables exert influence on the object in question. Natural factors of decay affect the object to some extent (this, of course, varies, depending upon the object) either by chemical changes or by eroding or covering the artifact. Cultural factors also come into play at that point, whether the culture is the same that accounted for the formation and deposition or whether it is a different culture in a different point in time. Some cultural variables that may affect the artifact include land use, which may disturb or destroy the object, and salvage, in the case of shipwrecks. The process of decomposition is ongoing and only ceases when the original object is ultimately destroyed. Figure 7 illustrates this formative process as it relates to Lake Superior shipwrecks.

In prehistorical archaeology, the primary context available to archaeologists is the archaeological context. The other two, i.e., depositional and systemic, can only be inferred from an analysis of archaeological materials or through such means as ethnoarchaeology and experimental archaeology. On the other hand, historical archaeologists

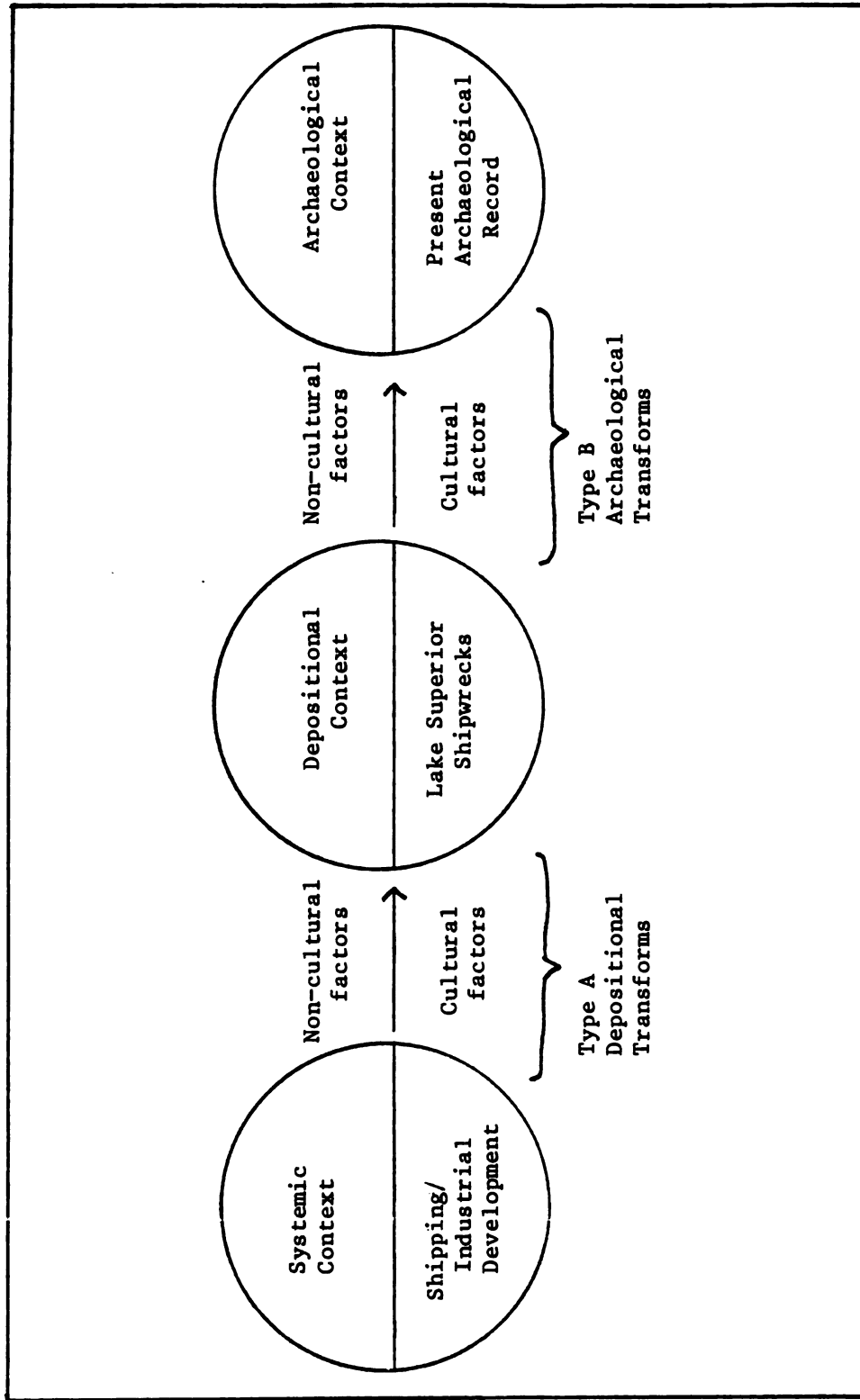


Figure 7. Shipwrecks and the formative process

have the benefit of historical documents, which enhance the knowledge available about the other two contexts and aid in uncovering the factors responsible for the transformation process. This is also true for shipwreck studies of Lake Superior. The historical documents available on the region provide information concerning many of the significant factors that influenced the production, deposition, and decomposition of historic period lake vessels. Both Type A and B transforms are discussed in the literature (although to varying extents) so that many of the factors responsible for the formation of the archaeological record are known. Table 10 presents some of those factors that will be considered in this study.

Table 10. Type A and Type B Factors

	<u>Type A</u> <u>Depositional</u> <u>Transforms</u>		<u>Type B</u> <u>Archaeological</u> <u>Transitions</u>
	Economic strategies		Salvage capabilities
	Shipping behavior		Salvage decisions
<u>CULTURAL</u>	Transportation routes	<u>CULTURAL</u>	Dredging operations
	Commodity trades		Sport diving
	Transportation technology		Legal protections
			Dumping
			Condition of wreck
			Dollar value of wreck
			Historical value
	Weather-storms, fog, winds		Water depth
	Geography-water depths,		Ice damage
	harbors,		Wave actions
<u>NON-</u>	navigation hazards	<u>NON-</u>	Water chemistry
<u>CULTURAL</u>	Natural resource distribution	<u>CULTURAL</u>	Lake hydrology

The factors presented in this table are by no means a definitive listing of all variables affecting shipwrecks. Rather, it is illustrative of the factor types that combine to form the underwater

archaeological record we now have. The shipping industry was a complex system of relationships involving economics, technology, and culture change. Likewise, the shipwrecks are reflections of these complexities as well as of numerous other factors, such as the physical environment.

Discussion of the formative process of the shipwreck record orders a wide range of variables into a unified system of thought. For analysis, all the factors that influenced vessel loss and spatial patterning can be grouped into two basic categories. The Type A depositional transforms are those factors that contribute to vessel loss, while Type B archaeological transforms affect vessels after loss has occurred. These concepts are useful primarily as heuristic devices for ordering and discussing the causal factors behind vessel loss and distribution.

Given the difference between the iron, grain, and coal trades on Lake Superior, it can be assumed that each industry would be affected differently by the factors outlined in Table 10. Theoretically, each industry will undergo a different formative process in the deposition and decomposition of related vessels, and the cultural and environmental variables responsible for the formative process will be different for each industry. Iron industry vessels, for example, may be differentially affected by the environment (weather, fog, etc.) because the cultural variables responsible for the transportation of iron (capital investment, decision making, chronology) are different from those of either the grain or coal trades. Figure 8 illustrates the combination of factors that result in vessel distributions. The interrelationships between cultural and environmental factors are such that as cultural factors

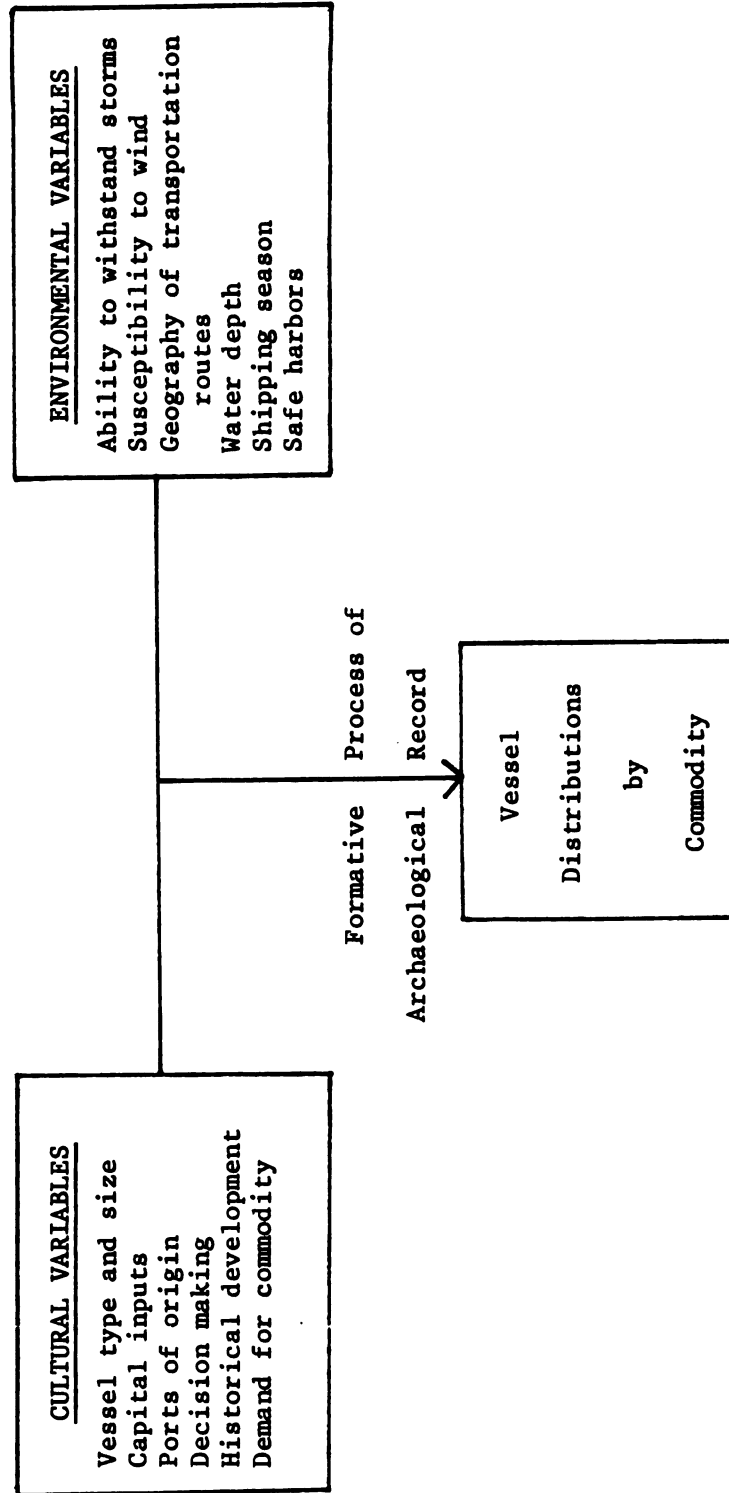


Figure 8. Variables in the formative process

change, the formative process as a whole changes and different vessel distributions result.

With this model of the formative process as a basis for the remainder of this study, a series of hypotheses can be presented that relates to spatial distribution of vessels. The following 21 hypotheses test relationships between variables that apply to the question of spatial patterning. The first 15 hypotheses deal with the depositional components (in this case--salvage) of vessels after deposition takes place. Collectively, these hypotheses will probe the relationships between key variables in the formative process as they relate to the mechanism of spatial distribution and patterning.

Hypothesis 1

The iron, grain, and coal industries operated under different procurement, distribution, transportation, and marketing conditions. The related commodities that were shipped across Lake Superior were transported along different trade routes with varying traffic frequency. Because of these and associated factors, it would be expected that there will be significant distributional differences between shipwrecks of these three different commodity trades.

Test implications for hypothesis 1:

- 1) There will be significant differences between the distribution of iron industry related shipwrecks and grain trade related shipwrecks for the period 1855-1920.
- 2) There will be statistically significant differences between the spatial distribution of iron industry related shipwrecks and coal trade related shipwrecks for the period 1855-1920.

- 3) There will be significant differences between the spatial distribution of grain trade related shipwrecks and coal trade related shipwrecks for the period 1855-1920.

Hypothesis 2

As the development of the Lake Superior region progressed and new water transportation routes were established, the flow of traffic across the lake was markedly altered. For example, as the iron industry expanded into new areas of production in the western portion of the region, the routes of ore transportation went through a series of modifications. Theoretically, corresponding shipwrecks would also have changed distribution if they are representative of past behavioral changes. Therefore, it would be expected that there will be significant distributional differences of shipwrecks by chronological period.

Test implications for hypothesis 2:

- 1) There will be significant distributional differences of shipwrecks by chronological period for iron, grain, and coal related vessels.
- 2) There will be significant distributional differences for all Lake Superior shipwrecks by chronological period.

Hypothesis 3

Within the iron and grain industries, there were different but related types of commodities traveling along similar routes of transportation. The grain trade involved the shipment of wheat, oats, barley, corn, and flour from the Duluth and Port Arthur ports. The iron industry out of Marquette focused on both the local production and shipment of pig iron as well as the movement of iron ore in the pre-1880

period. The particular qualities of these commodities may have resulted in different patterns of loss for each cargo type. Therefore, it would be expected that there will be significant distributional differences between related cargo types within the grain trade and iron industries.

Test implications for Hypothesis 3:

- 1) There will be significant distribution differences between lost vessels carrying a) oats, b) wheat, c) corn, d) barley, and e) flour from Duluth for the period 1870-1920.
- 2) There will be significant distribution differences between lost vessels carrying pig iron and vessels carrying iron ore for the period 1855-1880.

Hypothesis 4

Transportation on the Great Lakes is seasonal by nature and restricted to the months of ice-free navigation. This of course varies from year to year and is dependent upon the peculiarities of weather in the fall and spring months. When the navigation season is short because of an early winter or late spring, more cargo must be moved in less time than in a longer season. This results in greater traffic congestion on the Lakes during the navigable months, as well as more risktaking by companies and their vessel captains in order to insure that the maximum amount of cargo will be moved. On Lake Superior, the length of the shipping season was very important for the commodity trade in bulk cargoes because of the lack of alternate economical means of transportation during the winter months. For the most part, grain, coal, and iron ore were very dependent upon water transport for marketing and distribution. The combination of congested traffic and a need for maximized cargo movement may have had an effect on vessel loss. For these

reasons, it would be expected that there will be an inverse correlation between the length of the navigation season and the frequency with which vessels of different commodities were lost.

Test implication for Hypothesis 4:

- 1) More grain, ore, and coal shipwrecks will occur during years with short navigation seasons than with average or longer seasons.

Hypothesis 5

Throughout the history of the Great Lakes, weather has been a significant factor in vessel loss. On Lake Superior, the occurrence of storms, fogs, and other hazardous conditions has led to the demise of many vessels. Storms, for example, are particularly prevalent from mid-October to the close of navigation, while fog is of greater concern during the early months of the seasons when differences between water temperature and air temperature are conducive to fog-producing conditions. These conditions are of importance to all vessels on the lake regardless of the specific cargo being carried. Since weather is a natural factor, it should therefore effect all vessels carrying grain or coal to the same extent as those carrying ore. It would be expected that there will be no significant differences in the frequency of storm-related shipwrecks between vessels with cargoes of specific commodity types.

Test implication for Hypothesis 5:

- 1) Storm-related losses of vessels in the iron industry will be the same as losses in the coal or grain trades.

Hypothesis 6

The transportation routes followed by Lake Superior vessels were different in a number of ways. The distance of routes varied as did the navigational hazards encountered along those routes. These factors combined to make some routes more dangerous than others. Ports of origin for lost vessels provide information on the routes being traveled at different points in time. Since the port of origin is a reflection of the transportation route, and because all routes are both geographically and functionally different, it would be expected that there will be distributional differences between vessels of different ports of origin.

Test implication for Hypothesis 6:

- 1) Lost vessels from Duluth, Two Harbors, Ashland, Marquette, and Port Arthur will exhibit different patterns of distribution.

Hypothesis 7

The commodities of iron, coal, and grain operated under different procurement, transportation, distribution, and marketing systems. These differences may have resulted in corresponding differences in the types of vessels employed in the transportation of these commodities. Despite the fact that all three commodities were transported by bulk carriers, there may be some differences in vessel types. For example, because of the relatively greater importance of iron ore over grain, there may be differences in the types and sizes of vessels selected to carry each commodity. Iron ore vessels may be larger in average size than vessels of the grain trade for each respective period of time. Therefore, it would be expected that there will be statistically significant differences between the types of vessels employed in the

iron trade as opposed to either the grain or coal trades.

Test implications for Hypothesis 7:

- 1) There will be statistically significant differences in vessel types lost with cargoes of ore, as opposed to carriers of grain or coal.

Hypothesis 8

Because of the economics of water transportation, there was a steady increase over time in the size of lake vessels specializing in the movement of bulk cargoes such as iron ore, grain, and coal. The trend toward larger vessels required modifications in vessel design and structure, resulting in the gradual development of new types of vessels. The change from schooners, to propellers, to schooner-barges, and finally to steamers is well-documented for the Great Lakes, including the Lake Superior region. It would therefore be expected that shipwrecks will reflect the changes in vessel type that occurred over time.

Test implication for Hypothesis 8:

- 1) The types of vessels lost will vary in frequency by the chronological period of development.

Hypothesis 9

Lake Superior shipwrecks can be categorized into four major causal types of loss: 1) collision, 2) grounding, 3) fire, and 4) foundering. These types of loss were a result of a combination of natural and cultural factors affecting vessels in different ways. Because of the differences in vessel type, transportation routes, cargoes, and relative frequency of traffic, these types of loss may have

had greater influence on vessels of some industries than others. For example, the nature of grain cargoes may have a bearing on the types of loss associated with grain trade vessels. Therefore, it would be expected that there will be significant differences in the extent to which each commodity (i.e., coal, grain, iron) was affected by each of the four major types of loss categories.

Test implications for Hypothesis 9:

- 1) Fire will have affected vessels of the iron, coal, and grain trades to a significantly different extent.
- 2) Collision will have affected vessels of the iron, coal, and grain trades to a significantly different extent.
- 3) Foundering will have affected vessels of the iron, coal, and grain trades to a significantly different extent.
- 4) Grounding will have affected vessels of the iron, coal, and grain trades to a significantly different extent.

Hypotheses 10 and 11

The four types of vessel loss (i.e., collision, grounding, foundering, and fire) are different phenomena with different causal factors contributing to vessel loss. Those factors behind type of loss include transportation routes, navigational hazards, transportation technology, weather, etc. Because these same factors contribute to the distribution of shipwrecks in Lake Superior, there may be a link between the type of loss affecting a vessel and the location of the lost vessel. Therefore, it would be expected that there will be significant distributional differences between vessels of different loss categories.

Test implications for Hypothesis 10:

- 1) There will be significant distributional differences between vessels lost by collision, grounding, foundering, and fire.

In addition, since the type of loss is correlated with transportation routes and transportation technology that change through time, it would also be expected that the frequencies of vessels in each of the four loss categories will vary by chronological period.

Hypotheses 12 and 13

As vessel design changed through time, the ability of those vessels to cope with the hazards of the regions also changed. For example, the change from schooners to steam-powered craft decreased the length of travel from one point to another, providing greater independence from the unpredictability of winds and weather. To some extent, the new steam craft could better cope with the environment and would therefore be less prone to losses caused by winds or weather. But, the physical structure of the new steam vessels might have made them more vulnerable to other hazards. It would therefore be expected that there will be a correlation between some vessel types and corresponding types of loss.

Test implication for Hypothesis 12:

- 1) Vessel types such as schooners, schooner barges, propellers, wooden steamers, and iron steamers will correlate more with certain types of vessel loss than with others.

In addition, because some geographic areas may have placed more stress upon some vessel types than other areas, it would also be expected that there will be significant distributional differences between vessels of different types.

Test implication for Hypothesis 13:

- 1) Schooners, schooner-barges, propellers, wooden steamers, and iron steamers will exhibit significant differences in distributional patterns.

Hypothesis 14

The iron, grain, and coal commodities transported on Lake Superior varied in importance. Iron ore, for example, was transported in much greater quantities than either grain or coal. The relative importance of these commodities had a major effect on their transportation as well as on the frequency of traffic associated with each. If frequency of traffic is related to frequency of loss, then it would be expected that there will be a direct correlation between the relative frequency of traffic and the corresponding frequency of vessel loss.

Test implication for Hypothesis 14:

- 1) There will be a direct correlation between the frequency of iron industry traffic and the frequency of vessels lost in that industry.

Hypothesis 15

Vessels of the Lake Superior shipping industry traveled along different transportation routes because of the origins of the various commodities. The iron industry shipments originated from the ports of Two Harbors, Ashland, Duluth, and Marquette, while the grain trade operated primarily from Duluth and Port Arthur. The frequency of traffic from these ports in the associated commodities should therefore be reflected in the relative origins of the vessels lost in the corresponding chronological periods. For example, if 50 percent of the

grain shipments for the period 1870-1910 originated from Duluth, then 50 percent of the associated grain vessels lost should also have originated from that port. Therefore, it would be expected that there will be a direct correlation between the frequency of traffic in a given commodity from a given port and the associated frequency of vessels lost from that port.

Test implication for Hypothesis 15:

- 1) The ratio of iron industry vessels lost from Two Harbors, Ashland, Duluth, and Marquette will directly correlate with the frequency of traffic from those ports for the period 1855-1920.

Type B Archaeological Transform Hypothesis

Archaeological transforms are those cultural and environmental factors that influenced the formation of the archaeological record from the point of deposition to the present condition of the record. Although there are numerous factors that affect shipwrecks in Lake Superior, only those elements that are historically documented will be considered here. As future underwater archaeological investigations in the region are undertaken, increased knowledge of these factors will accumulate. Such studies will enhance our knowledge of archaeological transforms and their influence on the formation of our present underwater archaeological record.

Several hypotheses here relate to Type B transforms involving the element of salvage. Salvage is an important factor to consider because once vessels are deposited on shore or on the bottomlands, they become a potential source of the archaeological record. If they are consequently salvaged, they never become a part of the shipwreck record. The influences of salvage on the archaeological record can be learned

in part by comparing those vessels that were not salvaged to those vessels that were. Figure 9 illustrates the role of salvage in the formation of the shipwreck archaeological record. In order to understand a large portion of the mechanics of the Type B transformation process, it is essential to understand the salvage behavior that contributed to this process. Unfortunately, historical records involving salvage are incomplete and difficult to obtain. This situation necessitates that other measures be used to arrive at both the question of the extent to which salvage was accomplished and whether the vessels salvaged are spatially patterned.

If the locations and characteristics of salvaged shipwrecks are the same as those that were not, then the question of patterning is resolved. If, however, there are differences between the two groups (salvaged/not salvaged), then it is necessary to evaluate the extent of these differences as well as possible reasons for these differences. So the major hypothesis for this section is that if the depositional context is spatially patterned, then the archaeological context will be patterned in a like manner.

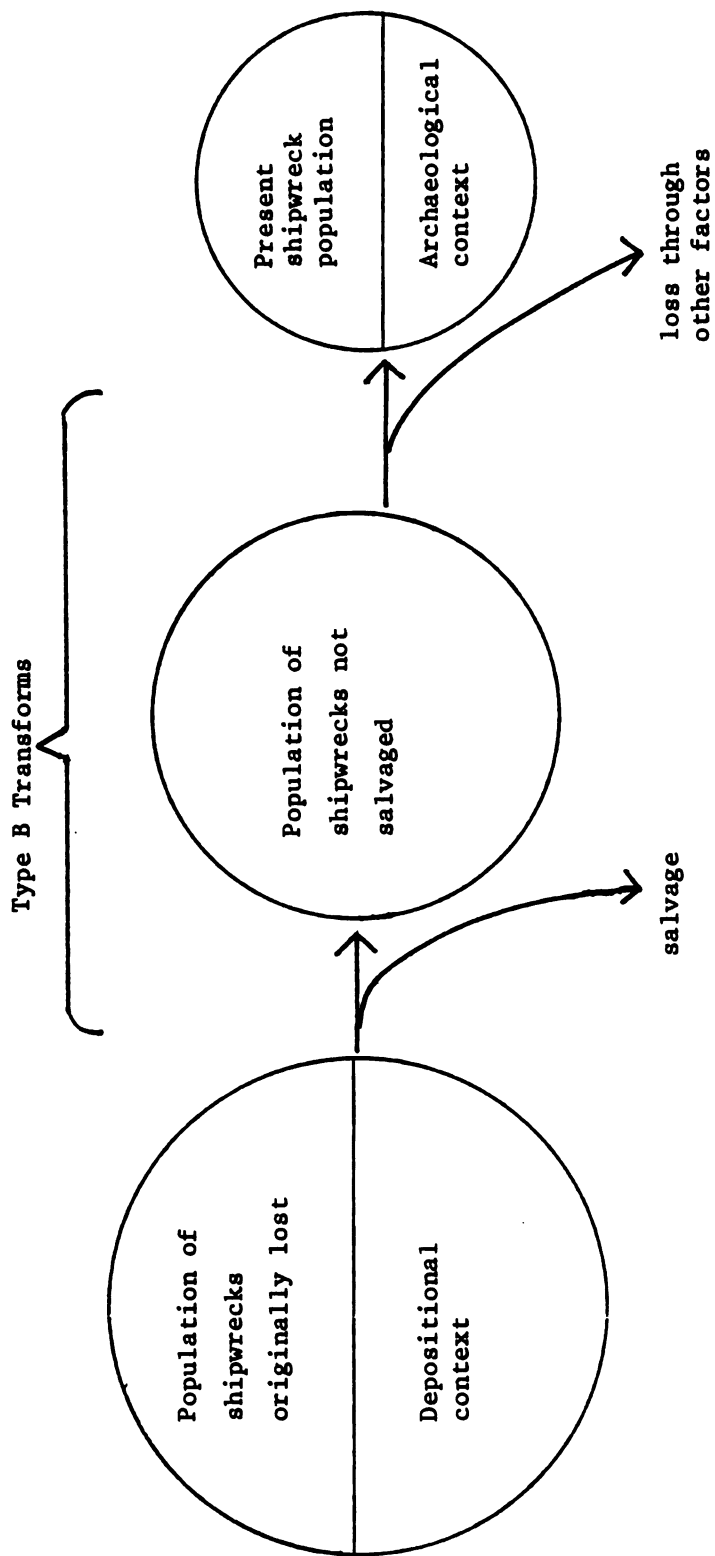
An investigation of this major hypothesis, as well as of the special conditions of salvage, will be outlined by the following hypotheses.

Hypotheses 16-21

Because of the factors discussed in this last section, we can hypothesize that if no relationship exists between certain factors and the salvagability of vessels then:

Hypothesis 16—There will be no significant differences between salvaged vessels and nonsalvaged vessels in regard

Figure 9. Salvage and the formative process



to vessel type.

Hypothesis 17--There will be no significant differences between salvaged vessels and nonsalvaged vessels in regard to the port of origin of the respective vessels.

Hypothesis 18--There will be no significant differences between salvaged vessels and nonsalvaged vessels in regard to the month of loss.

Hypothesis 19--There will be no significant distributional differences between salvaged vessels and nonsalvaged vessels for each commodity and for all vessels lost on Lake Superior.

Hypothesis 20--There will be no significant differences between salvaged vessels and nonsalvaged vessels in regard to the type of loss that brought about the respective shipwrecks.

Hypothesis 21--There will be no significant differences in regard to the frequency of salvage between vessels of the iron, grain, and coal trades.

CHAPTER V

METHODOLOGY

This chapter outlines and discusses the methods by which the hypotheses posed in chapter 4 will be tested and evaluated. Of the 21 hypotheses presented, as many as possible will be tested, given the limitations of the data base. In chapter 6, each individual hypothesis will be restated and tested using the techniques set forth in this chapter.

Shipwreck Attributes Defined

In order to test hypotheses concerning Lake Superior shipwrecks, it is necessary to define the types of data needed to complete the analysis. As previously discussed, shipwrecks are extremely diverse in their individual characteristics because of their chronology, function, or deposition. Despite this diversity, a number of attributes are common to all shipwrecks and serve to cross-cut the population of Great Lakes vessels. These attributes form the basis for the hypotheses presented in chapter 4 and will serve as the data base from which hypotheses can be analyzed in the following sections. Following is the list of key attributes that will be dealt with throughout the remainder of this study:

- 1) Shipwreck category - total loss vs. salvaged vessels;
- 2) Vessel type - schooner, schooner-barge, wooden steamer, steel steamer, misc.;

- 3) Date of loss - month and year;
- 4) Point of origin - Duluth, Two Harbors, Ashland, Marquette,
Port Arthur, misc.;
- 5) Location of loss - in Poisson grid;
- 6) Cargo - iron, grain, coal;
- 7) Type of loss - fire, grounding, foundering, collision;
- 8) Weather conditions at time of loss - presence/absence of storms,
fog.

Other attributes not related specifically to shipwrecks but rather to the shipping industry as a whole include:

- 9) Frequency of traffic from ports;
- 10) Routes of travel;
- 11) Frequency of loss;
- 12) Frequency of salvage.

These 12 attributes are essential to the successful testing of the hypotheses under consideration as well as the interpretation of the test results.

Abstraction of Attributes from Historical Sources

After the essential attributes needed to test hypotheses are defined, the data-gathering phase of the research can begin. In relation to this study, the body of information from which attribute data can be abstracted consists of several historical treatments of Great Lakes shipwrecks. These studies are either historical case studies on the losses of individual vessels, such as Wolff's (1979) recent work, or they are inventories of lost vessels compiled by various authors (Heden 1966; Winkleman 1971). These sources provide an

information base that deals with vessel attributes in either a direct or indirect manner. Wolff's (1979) study in particular was a detailed accounting of more than 1,000 Lake Superior accidents. These case studies have been abstracted for details on vessel attributes, and data sheets on each lost vessel have been prepared. As a base for this study, information on a total of 146 recorded shipwrecks has been abstracted from historical sources. The data sheets compiled for these vessels constitute a collection of vessel attributes that can be drawn upon and quantified to test the hypotheses.

A total of 146 lost vessels is relatively small in relation to the actual number of accidents that have occurred over the years, but it is the total population of known recorded losses for the period. Although there may be a few vessel losses that were not recorded for various reasons, given the reliability of the historical sources used, there is no reason to believe that many, if any, losses went unrecorded. The one limitation of the data is that the list of 146 vessels is small and that in approximately 20 percent of the cases, data on individual vessel attributes are partial. For example, case studies on some vessels fail to list one or more characteristics, such as point of origin or condition of loss, and are therefore not as complete as could be desired. But since most of the case studies allow for the full completion of data sheets, this does not appear to be a major liability. The lost vessels and their associated attributes are listed in a condensed form in Appendix B.

Quantification of Attributes

After data sheets are prepared from historical treatments of shipwrecks, the attributes listed on the sheets can be tabulated by category. For example, the type of vessel loss is of relevance to the testing of several hypotheses. Fire, grounding, foundering and collision are the four categories of loss into which most (if not all) types of vessel losses can be placed. From the data sheets, a simple count can be made of all vessels of known loss types and the relative frequencies can be tabulated for each of the loss categories. With a sample size of 146, all counts could be completed by hand without the use of computer assistance. Finer breakdowns of attributes can be made as desired so that, for example, the relative frequencies of loss types for both salvaged and totally lost vessels could also be tabulated if so desired. By this means, attributes can easily be cross-tabulated and quantified for comparisons using statistical tests. The limitation of a small sample size prevents some cross-tabulations from being used because of the very low frequencies encountered when numerous categories are used. A cross-tabulation between loss type and vessel type in regard to those vessels lost in storms (for example) would prove to be unfeasible because of partial data and low sample size. But most cross-tabulations are easily completed, as are simple attribute counts and presence/absence totals. The resulting raw scores of vessel or attribute counts are then analyzed using statistical techniques appropriate for nominal scale data.

Statistical Evaluation

The frequency counts of vessel attributes obtained from the data sheets are then evaluated through the use of several statistical

techniques. Those tests used in this study are 1) Poisson distribution for locational data, 2) Kolmogorov-Smirnov test for goodness of fit (used in conjunction with Poisson), 3) Contingency Chi Square, and 4) Kx2 Chi Square; the last two tests are used to test strength of associations between attributes. These will be briefly described here, and chapter 6 contains examples of each.

Poisson Distribution

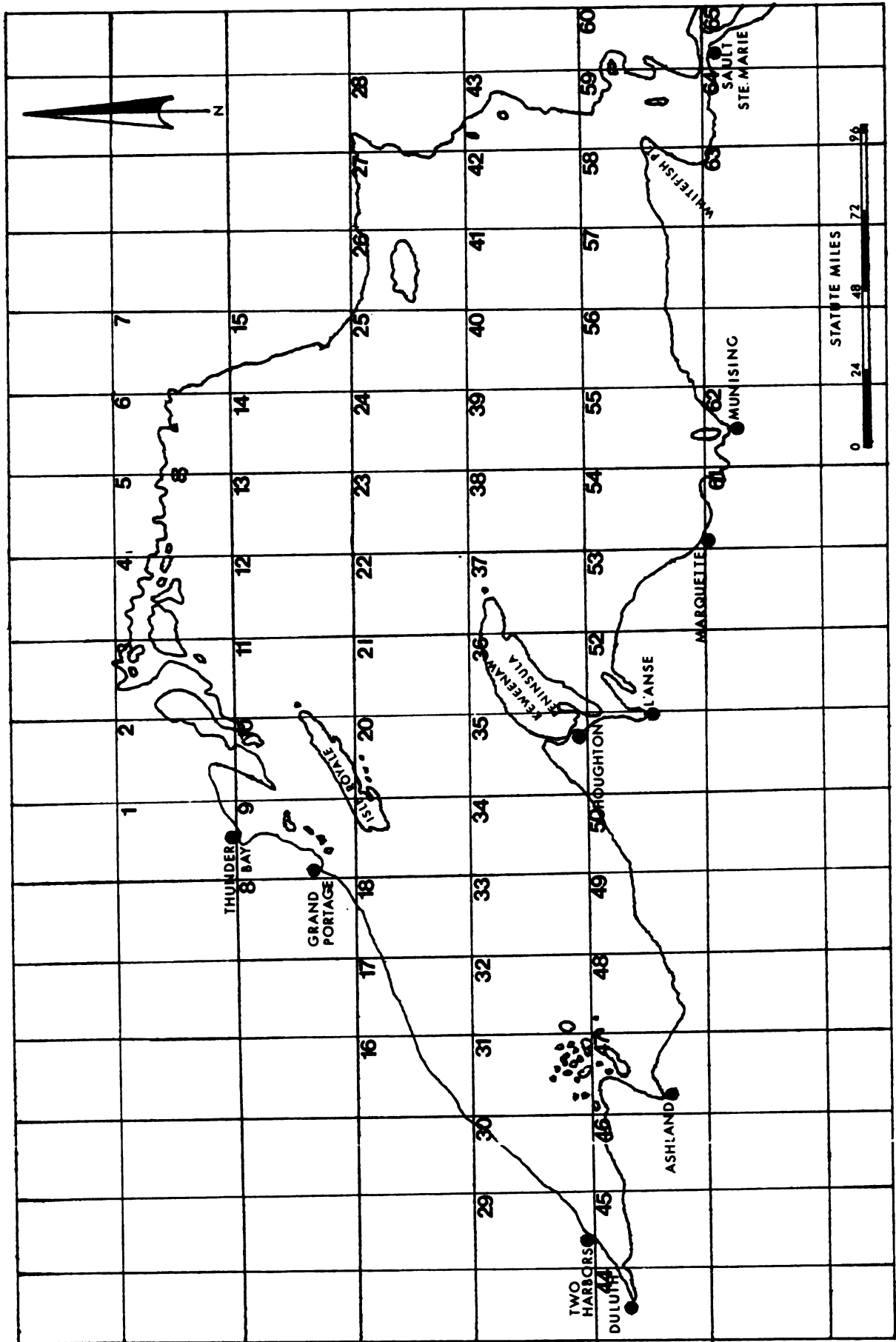
The Poisson distribution is a frequency distribution of rare events that is randomly patterned. When the Poisson distribution is compared to a distribution derived from a sample group, it can be determined whether or not that sample is likewise randomly patterned. This technique has been commonly used in probability mathematics and statistics since its first description in 1837 (Sokal and Rohlf 1969: 84), and in recent years, it has been applied to point pattern analysis by geographers and archaeologists (Hodder and Orton 1976:34). This latter application of Poisson is accomplished by means of a grid system imposed over a spatial plane and the tabulation of a variable's frequency of occurrence for each cell of the grid. The frequencies of variables occurring throughout the cells of the grid area are then compared with an expected (Poisson) distribution of those variables to determine if the variable is randomly or nonrandomly spatially patterned.

The use of Poisson in this study is particularly well-adapted to the determination of patterning among Lake Superior shipwrecks. By definition, shipwrecks are rare events and relatively scarce in relation to the tremendous amount of traffic on the lake in a given season. So the use of Poisson to evaluate spatial patterning of wrecks is very appropriate to small samples (Sokal and Rohlf 1969:81-95). And

since only 146 vessels are recorded lost on Lake Superior for the period in question, this also appears to be an appropriate test of the data.

For the use of Poisson on Lake Superior shipwrecks, a grid system was established across the lake based on latitude and longitude in 30-minute increments. The resulting grid system was composed of 65 rectangular cells of equal size (see Figure 10). Although theoretically these cells were of equal area, in actuality some cells were smaller than others because they fell on land areas that would not afford equal access as water arenas. For example, cell 58 on Whitefish Point is roughly half water and half land in area. This is in contrast to cell 42, immediately to the north, in which the surface area is 100 percent water. Theoretically, this differential cell size could have an impact on the frequency of vessels lost in the respective cells. Although this problem was carefully considered and adjustments in scores (or cells) could have been made to correct for such differential access, it was decided to leave the grid uncorrected. This decision was based on a cursory examination of wreck distributions to determine if cell counts were substantially higher for all-water cells versus partial-water cells. The results of this examination showed that shoreline cells were in actuality significantly more associated with wrecks than all-water cells. For example, cell 58, which was 50 percent water, had a total of 15 losses, while cell 42, which was 100 percent water, had no wrecks for the same period. It appears that although there may be some differential access across cells, there is no major block to patterning. If correction techniques were used, the results of the Poisson comparisons would be intensified rather than smoothed. Since this intensification is probably not necessary, the decision was

Figure 10. Poisson grid system



made to accept the 65-cell grid system despite its imperfections.

Once the grid system was imposed across the lake surface, the locations of wrecks were plotted based on the information provided in the historical sources. In approximately 75 percent of the cases, the location of loss was very exact--especially with groundings. For example, a location listed as a grounding one mile east of the Big Two Hearted River (cell 58) is easily plotted on the map and little difficulty is encountered assigning the loss to a grid cell. In other cases, a location listed X miles west of a certain point is less easily plotted on the map and is less exacting. There is little problem assigning these locations to a grid cell despite the lack of exact location because each grid cell is approximately 820 square miles in area. With the use of a grid system, if a location is mis-plotted by a couple of miles one way or the other, there is usually no problem placing vessels into incorrect cells. But if the number of cells was increased and the square area of each therefore decreased, some problems may occur. The 65-cell grid system used for this study was large enough to facilitate plotting of vessels yet small enough to detect subtle variations in patterning that would otherwise be masked with larger cells. In only a few cases was vessel location difficult to plot, and when such instances arose the plot was either done judgmentally if a reasonable assurance of accuracy could be made, or was not plotted if locational information was deemed insufficient. A location listed as "between Keweenaw Point and Whitefish Point" was not plotted because it lacked precise information. Of 146 total shipwrecks, only 13 (9 percent) could not reliably be plotted or did not have locational information provided.

Once vessels were located on the map and assigned a cell number, tabulations could be made in relation to particular attributes. For example, all vessels from the Marquette port could be tabulated by their frequency of occurrence in the grid cells. Some cells had no vessels from Marquette, while others had one or more. The frequencies of the Marquette vessel distributions in these cells could then be compared to an expected random Poisson distribution for determination of patterning. Vessels from Marquette could then be determined as being randomly distributed across the lake or nonrandomly distributed in either a "regular" or "clumped" pattern. The actual type of pattern can be determined by the computation of the coefficient of dispersion (CD), which is equal to the variance (s^2) divided by the mean ($\bar{x}$). This coefficient will be near 1 in distributions that are essentially Poisson, greater than 1 in clumped samples, and less than 1 in regular frequency distributions (Sokal and Rohlf 1969:88; Hodder and Orton 1976:34). In addition, since the variance is a function of the mean in a Poisson distribution, the variance will equal the mean when the distribution is randomly patterned.

The following formulae were used to calculate the relative expected frequencies of the Poisson distribution.

$$\frac{1}{e^{\bar{Y}}}, \frac{1}{e^{\bar{Y}}} \left(\frac{\bar{Y}}{1} \right), \frac{\bar{Y}}{e^{\bar{Y}}} \left(\frac{\bar{Y}}{2} \right), \frac{\bar{Y}^2}{2e^{\bar{Y}}} \left(\frac{\bar{Y}}{3} \right), \frac{\bar{Y}^3}{2 \times 3e^{\bar{Y}}} \left(\frac{\bar{Y}}{4} \right), \dots$$

where $\bar{Y}$ = sample mean and $e^{\bar{Y}}$ is the function of the mean. To obtain the absolute expected frequencies, the first term must be multiplied by n, the number of samples.

$$\hat{f}_0 = \frac{n}{e^{\bar{Y}}} , \quad f_1 = \left(\frac{n}{e^{\bar{Y}}} \right) \bar{Y} , \quad f_2 = \left(\frac{n\bar{Y}}{e^{\bar{Y}}} \right) \frac{\bar{Y}}{2} , \quad f_3 = \left(\frac{n\bar{Y}^2}{2e^{\bar{Y}}} \right) \frac{\bar{Y}}{3} , \dots$$

The variance, s^2 , can be determined through the following formula:

$$\text{Variance} = \frac{\sum fny^2}{n}$$

where y = # per cell - mean and f = observed frequency.

The coefficient of dispersion is calculated in the following manner:

$$\text{C.D.} = \frac{s^2}{\bar{Y}}$$

The actual computation of Poisson distributions will not be discussed in this study since it is a well-known technique. The reader is directed to Sokal and Rohlf (1969:81-95), Steel and Torrie (1960: 395-399), Doran and Hodson (1975:44-51), Hodder and Orton (1976:33-38), and Dacey (1968:172-180) for specifics on computation and applicability of Poisson distributions. Generally, however, the computation of Poisson is accomplished through the comparison of observed frequencies (such as the number of shipwrecks occurring in each of the 65 cells of the Lake Superior grid system) to computed expected frequencies that would be randomly distributed based on the mean and sample size. A goodness of fit test is then computed on the deviation between the observed and expected values and a determination of association is arrived at for various levels of significance. Both the Chi Square and Kolmogorov-Smirnov tests are applicable to this regard (Hodder and Orton 1976:38).

Kolmogorov-Smirnov Test of Goodness of Fit

In order to evaluate deviations between Poisson distributions and observed distributions, a goodness of fit test is required. For this purpose, the Kolmogorov-Smirnov test is especially well-suited because it is not subjected to the limitations of sample size and expected frequencies, as is the Chi Square (X^2) test. With the X^2 test, the observed frequencies must remain above 5, otherwise the tail of the distribution becomes distorted, affecting X^2 interpretation. This often necessitates the merging of groups to obtain the needed frequency, which in turn reduces the degrees of freedom and may obscure the deviations from the predicted Poisson distribution (Hodder and Orton 1976:38). With the Kolmogorov-Smirnov test, cumulative observed and expected frequencies are computed, as are cumulative deviations. This cumulative process eliminates the need for merging groups and is more reliable for testing small samples, such as is the case in this shipwreck study. The point of maximum deviation is then divided by the sample number (which is 65 because of the grid), and the statistic D is obtained. This statistic is then compared with critical values to determine confidence levels for accepting or rejecting the null hypothesis that the observed frequency distribution fits the Poisson (random) distribution. It is necessary to calculate the cumulative observed, F , and cumulative expected frequencies, $\hat{F}$,--these frequencies are subtracted to determine cumulative deviations and ultimately identify $d_{\max}$. Thus $d = F - \hat{F}$ and the largest value is labeled $d_{\max}$. The following formula is used to find D; $D = \frac{d_{\max}}{n}$. For further discussion of computation and applicability, see Siegel (1956:47-60) and Sokal and Rohlf (1969:571-575).

Contingency Chi Square

The contingency chi square test measures the extent of association or relation between two sets of attributes (Siegel 1956: 104-111, 175-179, 196-202; Sokal and Rohlf 1969:550-572). For the purpose of this study, this test was used to test the association between shipwreck attributes. Raw scores tabulated from data sheets provided the nominal scale data for tabulations of observed frequencies. Using two attributes, a contingency table is constructed of observed frequencies. From these frequencies, the expected frequencies for each cell are generated by multiplying the sum of rows by the sum of columns in the table and dividing by the total sample size. For example, an analysis of the association between different commodities (iron, grain, coal) and types of vessel loss (collision, fire, grounding, foundering) would result in a 12-cell contingency table with observed frequencies being the number of vessels in each of the industries that were wrecked due to each of the four categories of vessel loss. The sums of frequencies for loss type (rows) and commodity types (columns) would be computed and multiplied by corresponding cells for division by the total sample size. The Chi Square values for each cell would then be computed by summing the square of the deviations between observed and expected frequencies and dividing by the expected values.

$$X^2 = \frac{(f_i - \hat{f}_i)^2}{\hat{f}_i}$$

In this manner, a X^2 value for each cell is computed and the relative association between attribute elements can be interpreted by the size of this value. The final step of the process is to sum all the X^2 values

in each cell and to compare that figure to χ^2 tables for confidence evaluation. A total chi square value greater than the tabular value is grounds for rejecting the null hypothesis that there is no association between attributes (e.g., commodity and type of loss). This test is used extensively in this study to evaluate the degree of association between numerous combinations of vessel attributes.

Kx2 Chi Square

This test is mathematically similar to the contingency Chi Square just described but has different application. The Kx2 test provides a test of association between one attribute and two other attributes, the latter of which are variations of a single population. For example, the extent of association between type of vessel loss and the differential degree of salvaged versus totally lost vessels can be computed using the Kx2 Chi Square method. For the hypotheses that involve the attribute of salvaged/total loss, this test can be used to determine strength of association between the segments of that attribute and other attributes such as vessel type and loss type.

The computation of the χ^2 value is accomplished through an analysis of, for example, proportions between lost and salvaged vessels relative to the sample size. See Steel and Torrie (1960:370-371) for specifics of computation. The overall result of this computation process is a χ^2 value that can be evaluated for association at confidence levels. The minimum acceptable confidence level for both the contingency χ^2 and Kx2 χ^2 values is the .05 level. A computed χ^2 value greater than the confidence value is grounds for rejecting the null hypothesis that the ratio of salvaged to nonsalvaged (total loss)

vessels does not vary by more than chance from one attribute element (e.g., collision, fire, grounding, etc.) to another.

These four tests (Poisson, Kilmogorov-Smirnov, Contingency χ^2 , $K \times 2 \chi^2$) form the basis for the statistical evaluation of shipwreck attributes used in this study. In the following chapter examples of these tests will be provided as each hypothesis is analyzed.

Interpretation of Results

As the logical conclusions to the testing of hypotheses presented in chapter 4, chapter 7 will synthesize and interpret results. As a methodological step in this research, this will be the most important step toward evaluating the question of representativeness, around which this study is based. Since the subject will be treated in detail, it is unnecessary to describe here the specifics of that evaluation process. It is useful to say that the relationship between attributes are hierarchically ordered so that the results of hypotheses testing of earlier propositions will have a bearing on the interpretation of later propositions. For example, hypothesis 1 proposes that distributional differences will occur between shipwrecks associated with the iron, grain, and coal industries. The results of the testing of hypothesis 1 will then have a bearing on the interpretation of results (not the results themselves) of other hypotheses that deal with both distributional differences and commodity differences. Chapter 7 will describe in detail the process of interpretation and will discuss the specific links between hypotheses.

CHAPTER VI

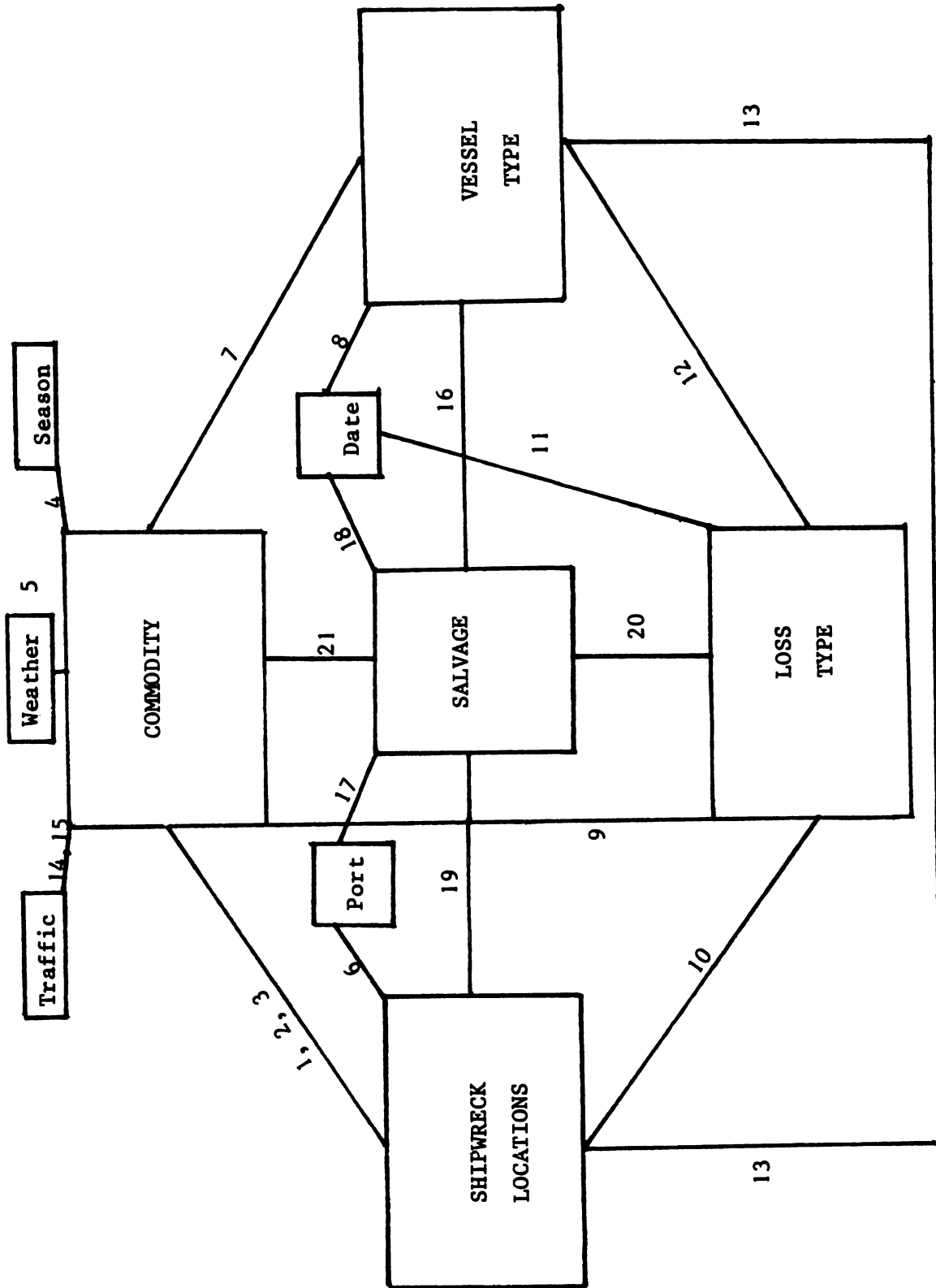
HYPOTHESIS TESTING

Introduction

The hypotheses tested in this chapter involve the formative process of the archaeological record as it applies to the spatial distribution of iron-, grain-, and coal-affiliated shipwrecks. Central to the question of spatial patterning are the individual variables that contribute to vessel loss, deposition, and decomposition, as well as those factors that influence the shipping industry as a whole. The 21 hypotheses tested here have been posed because of their relevance to the understanding of the patterning process. As previously discussed, the first 15 hypotheses relate specifically to the process of vessel loss, while the remaining six discuss the role of salvage in the current deposition of vessels.

It is important to outline the relationships between the variables being tested as well as the specific hypotheses used to accomplish the tests. The variables examined in this chapter are closely interrelated and often have an impact on one another through direct or indirect means. These variables can be viewed as a systems framework that links each element together into a cohesive network. To establish the association between the variables, 21 hypotheses were created to explore these relationships as they apply ultimately to the spatial distribution of shipwrecks in Lake Superior. Figure 11 graphically illustrates the variables under consideration along with

Figure 11. Variables under consideration



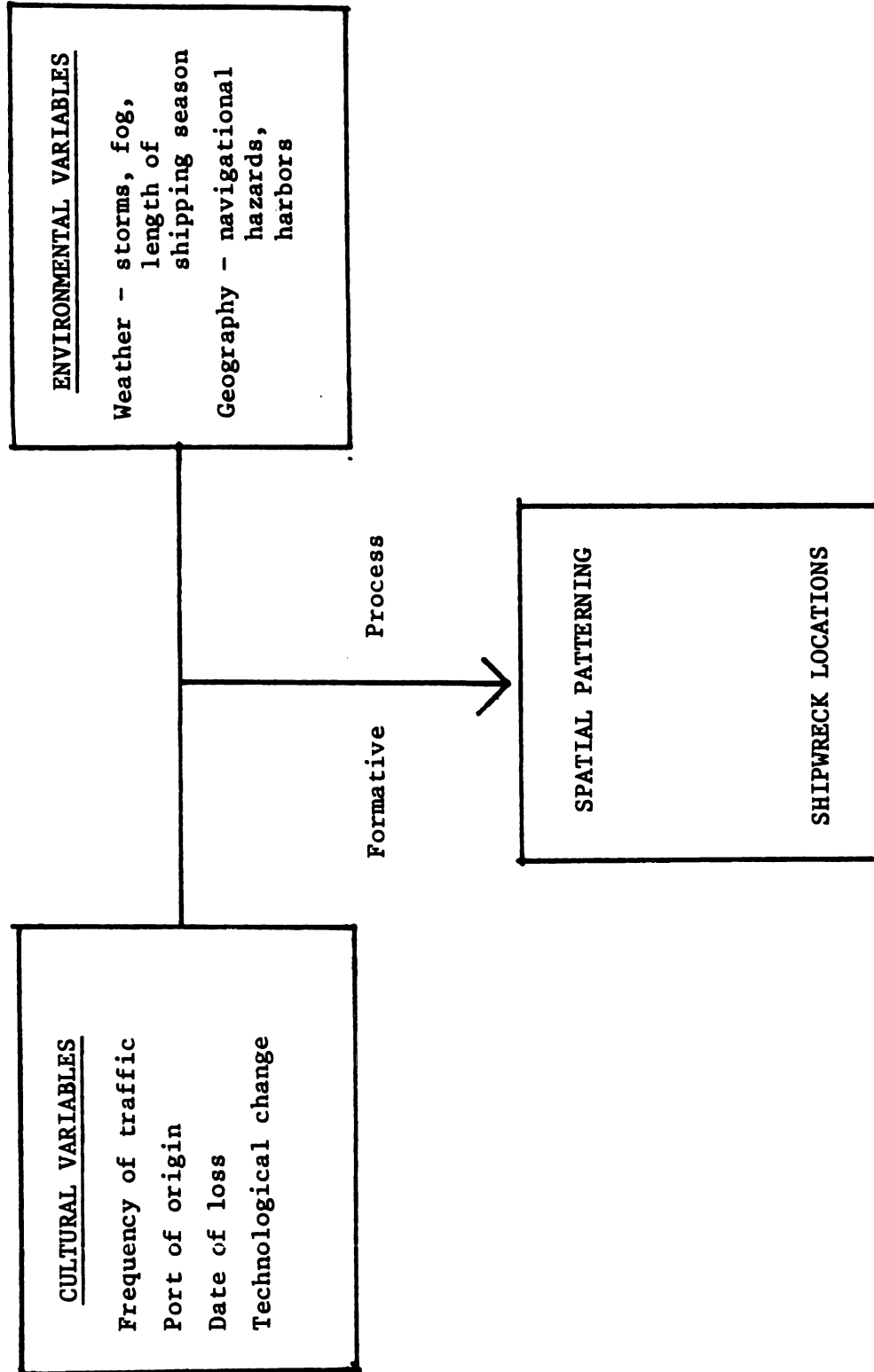
the numbers of the specific hypotheses designed to test the associations between these variables. As this diagram shows, ten major variables are dealt with in this study. These variables are characteristics of shipwrecks that are documented in the historical record and that are of use to the understanding of the shipwreck phenomena. These are: 1) commodity affiliation (iron, grain, coal); 2) frequency of traffic; 3) weather; 4) seasonality of shipping; 5) location of lost vessels; 6) port of origin; 7) degree of salvage; 8) date of loss; 9) vessel type; and 10) type of loss. These characteristics of shipwrecks are used in the 21 hypotheses presented in chapter 4. Lines connecting each of the shipwreck variables illustrate the presence of one or more hypotheses used to test the relationship between these variables. The hypotheses numbers shown on the diagram correlate with the hypotheses tested in this chapter. For example, hypothesis 1 tests the relationship between commodity affiliation (iron, grain, coal) and the spatial patterning of Lake Superior shipwrecks. The function of this diagram is to illustrate the role of each hypothesis in linking two or more variables for study. As Figure 10 shows, there are many variables that are not directly linked to one another and that will not be tested. The hypotheses presented are therefore only testing those relationships that are pertinent to the question of patterning and that can be tested by the available data. Many questions will be left unasked in this study because of a lack of data or relevance to the issue at hand. Hopefully, future studies using a larger data base or a different topical emphasis will address some of the relationships not explored in this research.

Hypothesis 1-15 examine the variables that contribute to vessel loss and deposition (Type A transforms), while hypotheses 16-21 explore

the factors, such as salvage, that contribute to the process of decomposition (Type B transforms). Within the outline provided, the role of each hypothesis can be viewed as a mechanism for testing the relationships between the variables presented. As Figure 12 shows, it is obvious that some variables play a more important role in testing the relationship to shipwreck locations than others. The elements of commodity affiliation, vessel type, loss type, and salvage are of particular importance to an understanding of the ultimate spatial distribution of shipwrecks. Such characteristics as weather, seasonality, and frequency of traffic are also important to the investigation of wreck distributions but in a more indirect manner. These three variables are tested through their influence on individual commodities, which in turn can be related to the question of spatial patterning. In this way, all variable relationships can be tested as they relate to the specific focus of this study.

Another way to view these key variables is through an elaboration of Figure 8, presented in chapter 4. Because these variables have an ultimate effect upon patterning of shipwrecks, their role in the formative process must be outlined. Figure 12 illustrates the variables that affect the spatial distribution of iron, grain, and coal related shipwrecks. The cultural factors of economic demand, transportation routes, chronology of development, and technological change are reflected in such variables as frequency of traffic, port of origin, date of loss, and vessel type respectively; environmental variables of weather and geography influence vessel loss due to storms, fog, navigational hazards, etc.; the interaction of cultural and environmental variables contributes to vessel loss and distribution of resulting shipwrecks.

Figure 12. Variables affecting iron, grain, coal vessels



For each industry (iron, grain, coal), the formative process is different because the cultural variables are different. The iron industry was different from either grain or coal because of numerous factors discussed in earlier chapters. The hypotheses that are tested in this chapter seek to understand the effect of commodity differences in the spatial patterning of shipwrecks. The question is "do iron industry wrecks pattern in the same manner and with the same characteristics as the other two commodities, and if so, why?" The answer to this question and others will depend upon the results of this testing process.

Hypotheses

The following hypotheses deal with numerous factors involved in the process of spatial patterning and deposition. These factors are either cultural or environmental in nature and often involve combinations of one or more elements. As a whole, the first section of hypotheses represent Type A transforms. Such factors as 1) distributional differences within and between industrial commodities, 2) frequency of vessel traffic, 3) vessel origins and transportation routes, 4) transportation technology, 5) period of navigation, 6) weather patterns, and 7) types of vessel loss will be examined through the formation and testing of related hypotheses.

The second section of hypotheses deals with Type B factors and involves the cultural and noncultural influences upon the archaeological record after deposition takes place. Because this study is primarily based on the historical record, Type B transforms are necessarily somewhat under emphasized. It is hoped that as future archaeological endeavors probe the underwater shipwreck record, knowledge of these factors can be greatly expanded. Until that time, the historical

record must suffice despite its potential inaccuracies and information gaps.

Type A Depositional Transform Hypotheses

The overriding hypothesis concerning the transformation of the systemic context into the depositional context is the degree to which the latter is a patterned representation of the former. Re-stated, this hypothesis postulates that shipwrecks originally deposited on the bottomlands are spatially reflective of past patterned cultural (shipping) systems, so patterns of vessel loss will be found that will closely approximate the system from which they developed. With this as the major hypothesis for this study, the following hypotheses can be presented for testing.

Hypothesis 1

Based on the information provided in chapter 3, it is hypothesized that there will be significant distributional differences between shipwrecked vessels of the iron, grain, and coal trades. This hypothesis means that there would be distinguishable patterns for each of the three industries, and that these patterns would be spatially nonrandom. In order to test this hypothesis, it is first necessary to determine if the patterning of wrecks is spatially random or nonrandom, and if nonrandom, to describe the actual patterning. Chapter 7 will discuss reasons for randomness or nonrandomness of patterning.

Test for Hypothesis 1

The procedure used to test hypothesis 1 will be to compare frequency distributions of each industry to a Poisson distribution in order to test for random or nonrandom patterning. To do this, the

locations of wrecks (both total losses and salvaged vessels) for each industry were plotted onto the 65-cell grid and the observed frequencies for each cell recorded. The distribution of vessels for all three industries combined can be seen in Appendix C. From this table, a frequency listing of the number of cells that contain zero, one, two, three . . . n wrecks per cell can be generated (see Table 11). The mean can be computed by summing the multiple of the wrecks per cell (column 1) times observed frequency (f, column 2) and dividing by the number of squares in the grid (65). In this case, the mean is 2.046. Using the mean and it's function, the expected frequency ($\hat{f}$) can be generated. This frequency is distributed in a Poisson manner and is representative of a random distribution.

Table 11. All commodities: total and salvage combined

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	26	8.40
1	18	17.19
2	8	17.53
3	2	11.99
4	3	6.13
5	2	2.51
6	1	.86
7	0	.25
8	1	.06
9	0	.02
10	0	.003
11	0	-----
12	1	-----
13	0	-----
14	3	-----

Using the Kolmogorov-Smirnov test for goodness of fit, the cumulative observed frequency (F), cumulative expected frequency ($\hat{F}$), and cumulative deviation ($F - \hat{F}$) can be computed. Table 12 provides a synopsis of the results.

Table 12. Poisson results for all Lake Superior shipwrecks

$\bar{x}$	s^2	CD	D
2.046	13.135	6.420	.28232

As can be seen in this table, the very high s^2 and CD demonstrate a clumped distribution not in Poisson fashion. The D value of .28323 is sufficient for a rejection of the null hypothesis that "the distribution of Lake Superior shipwrecks is randomly patterned" at the .01 (.19877) level of significance. Therefore, Lake Superior shipwrecks clearly have a nonrandom spatial distribution. The fact that large clusters of wrecks occur in zones 36, 54, 56, 58, and 59 (see Appendix C), indicates nonrandom distribution.

Commodity A - Iron

The plotting of the iron industry wrecks on the Poisson grid system resulted in the distribution shown in Appendix C-1. From these frequencies, Table 13 generated the following results.

Table 13. Iron: total and salvage combined

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	43	22.14
1	9	23.84
2	6	12.84
3	1	4.61
4	1	1.24
5	1	.27
6	0	.05
7	1	.01
8	0	.001
9	1	-----
10	1	-----
11	1	-----

The mean, variance, coefficient of dispersion, and D statistic were computed from this table (see Table 14).

Table 14. Iron: salvage and total losses combined

$\bar{x}$	s^2	CD	D
1.077	5.517	5.123	.32090

The high s^2 and CD values indicate a nonrandom distribution. The goodness of fit test confirms this, and the D value calls for the rejection of the null hypothesis "that the spatial distribution of iron industry shipwrecks is randomly patterned" at the .01 level of significance (.1988). Shipwrecks of the iron industry are therefore highly patterned.

The clustering of iron-related vessels in zones 36, 54, 56, 58, and 59, as seen in Table 1c, Appendix C, is the likely cause of this nonrandom distribution. These are the same zones that were most frequently occupied by the distribution previously discussed.

Commodity B - Grain

The plotting of grain trade vessels on the Lake Superior grid resulted in the distribution shown in Appendix C-1c. From these frequencies, Table 15 was generated.

Table 15. Grain: total and salvage combined

<u>number of wreck/cells</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	42	39.73
1	18	19.55
2	3	4.81
3	0	.79
4	2	.10

Table 16 summarizes the statistical computations derived from this table.

Table 16. Grain: salvage and total losses combined

$\bar{x}$	s^2	CD	D
.492	.711	1.445	.03490

The low variance and coefficient of dispersion indicate slight patterning, but the D statistic illustrates that the pattern (if any) is not significant at the .05 level (.16567). Therefore, the null hypothesis that "grain vessels will be spatially distributed in a random (Poisson) fashion" is accepted.

Commodity C - Coal

The distribution of coal carrying vessels on the Lake Superior grid system resulted in the distribution shown in Appendix C - 1a. From these, distributions Table 17 was computed.

Table 17. Coal: total and salvage combined

<u>number of wrecks/cells</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	45	39.11
1	12	19.87
2	5	5.05
3	2	.03
4	0	.004
5	1	.001

Statistical computations derived from this table are summarized as follows:

Table 18. Coal: salvage and total losses combined

$\bar{x}$	s^2	CD	D
.508	.896	1.764	.09060

The low variance and coefficient of dispersion indicate little patterning of vessels within the grid. The D value is not significant at the .05 level (.16567), and the null hypothesis that "coal-carrying vessels will be randomly distributed" is accepted.

Hypothesis 1 Summary and Results

The results of the four Poisson tests indicate that the iron industry wreck distributions are highly patterned. Five specific locations add to this patterning. In contrast, the grain- and coal-related vessels are random in distribution and do not exhibit the cluster patterning found with iron. Hypothesis 1 is therefore rejected because all commodity-related distributions are not nonrandomly distributed. The interpretation of the results shown here will be undertaken in the following chapter 7.

Hypothesis 2

This hypothesis states that there will be significant distributional differences of shipwrecks by chronological period. It would be expected that iron, grain, and coal vessels would distribute differently for each period and that shipwrecks as a whole would likewise be distributed differently for each period. In order to confirm this hypothesis, it would be necessary to demonstrate that wreck distributions are nonrandom for each period and that these patterns are different for each period under consideration.

Test for Hypothesis 2

In order to evaluate for patterning, the Poisson test was initiated against various shipwreck categories for three chronological periods. Since the focus for this study is the period 1855-1930, three equal 25-year segments were created on arbitrary grounds. These segments were 1) 1855-1879, 2) 1880-1904, and 3) 1905-1929. For each of these periods, shipwrecks were categorized further by separate commodity affiliation and by combined industry totals to form the following 12 groupings:

1. Iron - 1855-1879
2. Iron - 1880-1904
3. Iron - 1905-1929
4. Grain - 1855-1879
5. Grain - 1880-1904
6. Grain - 1905-1929
7. Coal - 1855-1879
8. Coal - 1880-1904
9. Coal - 1905-1929
10. All vessels - 1855-1879
11. All vessels - 1880-1904
12. All vessels - 1905-1929

These groups were then plotted separately onto the 65-cell Poisson grid for Lake Superior, and frequency distributions were recorded. These are shown in Appendix C, 2a-1. The means and expected values can be tabulated from these tables using the Poisson formulae previously discussed. Tables 19-30 illustrate these distributions.

Table 19. Iron 1855-1879

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	60	53.22
1	1	10.64
2	1	1.06
3	2	.07
4	1	.004

Table 20. Iron 1880-1904

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	49	41.04
1	11	18.88
2	2	4.36
3	1	.67
4	0	.08
5	0	.007
6	2	-----

Table 21. Iron 1905-1929

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	52	42.24
1	7	18.21
2	3	3.92
3	2	.56
4	0	.06
5	0	.005
6	0	-----
7	0	-----
8	0	-----
9	1	-----

Table 22. Grain 1855-1879

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	61	61.16
1	4	3.67

Table 23. Grain 1880-1904

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	52	50.82
1	10	12.50
2	3	1.53

Table 24. Grain 1905-1929

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	54	54.02
1	10	9.99
2	1	.93

Table 25. Coal 1855-1879

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	63	62.08
1	1	2.86
2	1	.07

Table 26. Coal 1880-1904

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	56	53.24
1	6	10.65
2	2	1.07
3	1	.07

Table 27. Coal 1905-1929

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	50	50.02
1	13	13.10
2	2	1.72

Table 28. Iron, grain, and coal combined 1855-1879

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	57	47.78
1	3	14.72
2	2	2.27
3	1	.23
4	0	.02
5	2	.001

Table 29. Iron, grain, and coal combined 1880-1904

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	41	26.22
1	11	23.80
2	4	10.81
3	6	3.27
4	0	.74
5	1	.14
6	0	.02
7	0	.003
8	1	-----
9	1	-----

Table 30. Iron, grain, and coal combined 1905-1929

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	36	27.04
1	15	23.72
2	10	10.32
3	2	3.02
4	1	.66
5	0	.12
6	0	.02
7	7	.002
8	0	-----
9	0	-----
10	0	-----
11	0	-----
12	1	-----

Using these expected values, the variance, CD, and D can then be calculated using the respective formulae. A summary of the results can be seen in Table 31.

Table 31. Summary of results

<u>Group</u>	<u>Period</u>	<u>$\bar{x}$</u>	<u>s^2</u>	<u>CD</u>	<u>D</u>
Iron	1	.200	.560	2.800	.10431
Iron	2	.462	1.325	2.868	.12246
Iron	3	.431	1.631	3.785	.15015
Grain	1	.060	.058	.963	.00300
Grain	2	.246	.278	1.130	.01800
Grain	3	.185	.181	.980	.00080
Coal	1	.046	.075	1.626	.01415
Coal	2	.200	.314	1.570	.04300
Coal	3	.262	.255	.972	.00300
All Vessels	1	.308	.982	3.190	.14185
All Vessels	2	.908	3.038	3.346	.22739
All Vessels	3	.877	2.816	3.210	.13785

The critical value for D, significant at the .05 level, is .16567 so that only one of these 12 categories is nonrandom. The null hypothesis that "vessels in these categories will be distributed in the

Poisson fashion" was therefore accept in the 11 cases. The one exception--all vessels, period 2 1880-1904--was the only case in which the distribution formed a nonrandom pattern.

Hypothesis 2 Summary and Results

The results of the Poisson tests indicate that for the most part, shipwreck distributions for individual chronological periods have a random spatial patterning. Therefore, Hypothesis 2 is rejected. In the case of category 11 (all vessels 1880-1904), a significant pattern of vessel distribution was noted with major clustering of vessels in zones 54, 58, and 59. Clustering was also noted for some of the following categories, and those zones of most frequenc occurrence are as follows:

<u>Category</u>	<u>Zone</u>
1	58
2	58,59
3	36
10	54,58
11	54,58,59
12	36

Despite the clustering noted above, in all cases except for category 11 it was not sufficient to cause significance at the .05 level.

Hypothesis 3

As stated in chapter 4, this hypothesis suggests that there will be significant distributional differences between related cargo types within the grain trade and iron industry. For example, the distribution of grain- and flour-related vessels would be hypothesized to be different, as would be ore- and pig iron-related vessels. When this hypothesis was originally proposed, the extent of the data base was not

known. Since that time, it has been learned that only three vessels carrying pig iron were lost and that a small proportion of grain trade vessels carrying flour or non-wheat cargoes were lost. Therefore, the sample size is not sufficient to evaluate distributions using statistical measures. A cursory examination of distributions of commodity-related variants did not reveal any patterning that appeared to be clustered.

Although this hypothesis is not testable given the small sample size, it is still a valuable question to pose, and may be useful if applied to a sample of vessels from another geographic region.

Hypothesis 4

Hypothesis 4 states that there will be an inverse association between the length of the navigation season and the frequency with which vessels of different commodities were lost. That is, iron-, grain-, and coal-carrying vessels should all be lost with greater frequency during years with short navigation seasons than in years with longer seasons. In order to confirm this hypothesis, it is necessary to demonstrate that an association exists and that the association is inverse.

Test for Hypothesis 4

The years between 1855 and 1930 were divided into three groupings based on the length of the navigational season for each respective year. Since the range for season length was 195-251 days per year, this span was divided into three arbitrary segments of equal length. These were:

1. Seasons with 213 days per year or less - short seasons

2. Seasons with 214-233 days per year - average seasons
3. Seasons with 234 days per year or more - long seasons

All vessels were placed into these categories based on the year of their loss and the length of season for each specific year. Table 32 lists the calculation of season length for each year.

For each of the three groups formed, vessels were further subdivided into commodity association so that nine categories resulted. The frequencies of vessels in each of these categories were then tabulated and a contingency Chi Square test administered with the results shown in Table 33. A cumulative X^2 value of .441 was not found to be significant at the .05 level with four degrees of freedom (9.49). Therefore, the null hypothesis that "there will be no association between the length of navigational season and differential loss in each industry category" is accepted. Iron-, grain-, and coal-associated vessels were lost in approximately the same proportions in each of the long, average, and short navigational seasons.

Hypothesis 4 - Summary and Results

Based on the results of the X^2 test, hypothesis 4 is rejected. Rather than being an inverse association between vessel loss and length of season, a direct association was indicated. For each industry, the longer the period of navigation, the higher the frequency of loss. Years with short navigational seasons experienced fewer losses of vessels than years with long seasons. The reason behind this association may be a function of the gradual lengthening of navigational seasons in general--resulting in more years with long seasons and hence more total wrecks. This explanation seems more likely than the assumption that a few extra days would cause a significant increase in vessel loss.

Table 32. Length of navigational season

<u>Year</u>	<u>Length of Season</u>	<u>Year</u>	<u>Length of Season</u>
1855	163	1893	218
1856	208	1894	233
1857	205	1895	230
1858	216	1896	236
1859	209	1897	234
1860	198	1898	245
1861	195	1899	230
1862	214	1900	237
1863	214	1901	229
1864	236	1902	262
1865	217	1903	250
1868	216	1904	221
1869	240	1905	246
1870	216	1906	248
1871	204	1907	232
1872	199	1908	230
1873	196	1909	234
1874	203	1910	247
1875	203	1911	237
1876	206	1912	239
1877	211	1913	243
1878	208	1914	238
1879	216	1915	246
1880	201	1916	243
1881	211	1917	237
1882	227	1918	234
1883	224	1919	250
1884	231	1920	251
1885	209	1921	261
1886	243	1922	251
1887	234	1923	235
1888	210	1924	242
1889	233	1925	239
1890	227	1926	221
1891	225	1927	237
1892	236	1928	224
		1929	236

Table 33. Results

Short Season			
	<u>observed</u>	<u>expected</u>	<u>χ^2</u>
Iron	7	7.71	.07
Grain	4	3.60	.04
Coal	4	3.70	.02
Average Season			
	<u>observed</u>	<u>expected</u>	<u>χ^2</u>
Iron	22	22.62	.02
Grain	10	10.54	.03
Coal	12	10.85	.12
Long Season			
	<u>observed</u>	<u>expected</u>	<u>χ^2</u>
Iron	44	42.67	.04
Grain	20	19.87	.001
Coal	19	20.46	.10

Hypothesis 5

This hypothesis states that there will be no significant differences in the frequency of storm-related shipwrecks between vessels affiliated with each specific commodity. That is, iron industry vessels should be affected by storms at the same rate as the grain or coal trade vessels.

Test for Hypothesis 5

The test for this hypothesis can be accomplished using a Kx2 Chi Square analysis, which tests the extent to which vessels of the iron, grain, and coal trades are differentially associated with loss due to storm. Data from Appendix B are used to determine which vessels were lost in storm-related accidents, and then those vessels are categorized by industry affiliation.

The results for the X^2 test are given in Table 34.

Table 34. Results of X^2 test

<u>Commodity</u>	<u>Storms</u>	<u>No Storms</u>	<u>Total</u>	<u>P</u>	<u>PA</u>
Iron	35	38	73	.4795	16.783
Grain	28	7	35	.8000	22.400
Coal	<u>23</u>	<u>12</u>	<u>35</u>	.6571	<u>15.113</u>
	86	57	143		54.296

The X^2 value of 10.75 is significant at the .01 level with two degrees of freedom (9.21). Therefore the null hypothesis that "the ratio of vessels lost in storms to those vessels not lost in storms does not vary by more than chance from one industry to another" is rejected. Clearly, some industries are more affected by storm loss than others.

Hypothesis 5 - Summary and Results

Based on the results of the X^2 test, hypothesis 5 is rejected. The key differentiations lie in the fact that grain vessels were affected by storms 80 percent of the time as compared to 48 percent for iron and 66 percent for coal. These figures are important because storms may have a randomizing effect on vessel distributions by blowing vessels off course.

Hypothesis 6

This hypothesis states that there will be significant distributional differences between vessels of different ports of origin. In order to confirm this hypothesis, it must be demonstrated that vessels from particular points of origin (during the voyage in which they were lost, not their point of registry) are nonrandomly distributed. If they are patterned in their distribution, they must also be patterned in different spatial configurations.

Test for Hypothesis 6

Since iron and grain are the only two downbound cargoes, and coal moves upbound, only data on the former two commodities will be used to test this hypothesis. The reporting of vessel origins was not detailed in vessel case studies, so only 85 vessels are available for use. Destinations for coal vessels are so poorly recorded (only approximately 15 percent) that again, the decision was made to eliminate coal vessels entirely.

As the first step for the testing process, the five major ports on Lake Superior were used as origin points for lost vessels. The five ports of Marquette, Ashland, Two Harbors, Duluth/Superior, and

Port Arthur/Fort William accounted for 99 percent of vessel origins; other ports were not considered. In the case of Duluth/Superior and Port Arthur/Fort William, the ports have been combined because of their relative proximity to one another. All the vessels from each of these five ports were plotted onto the grid system and frequency distributions for each can be found in Appendix C, 6a-e. From these frequencies, Tables 35 through 39 were generated with the following results.

Table 35. Marquette

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	58	45.65
1	2	16.16
2	2	2.86
3	0	.34
4	0	.03
5	1	.002
6	2	-----

Table 36. Ashland

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	59	54.90
1	2	9.28
2	3	.78
3	1	.04

Table 37. Two Harbors

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	61	61.90
1	4	3.76

Table 38. Duluth/Superior

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	43	35.68
1	13	21.41
2	5	6.42
3	3	1.28
4	0	.19
5	0	.02
6	0	.002
7	1	-----

Table 39. Port Arthur

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	57	57.47
1	8	7.07

From these tables, the means, variance, coefficient of dispersion, and D statistic were computed and summarized in Table 40.

Table 40. Results

Port	$\bar{x}$	s^2	CD	D
Marquette	.354	1.521	4.296	.19000
Ashland	.169	.326	1.930	.06307
Two Harbors	.062	.058	.940	.01015
Duluth	.600	1.363	2.272	.11261
Port Arthur	.123	.108	.876	.00708

Hypothesis 6 - Summary and Results

It can be seen from this table that Marquette is the only port associated with a nonrandom distribution. The high variance in relation to the mean, high coefficient of dispersion and the significant D statistic are illustrative of a nonPoisson distribution. Vessels from

Marquette are therefore nonrandomly patterned and the null hypothesis that "vessels from Marquette will be randomly distributed across the grid" was rejected at the .02 level of significance (.18525). For the ports of Duluth, Port Arthur, Ashland, and Two Harbors, there were insufficient grounds for rejecting the null hypothesis and the patterns are therefore random.

As can be seen from Table 6a, Appendix C, the Marquette distribution is clustered in zones 54, 56, and 58 and is largely responsible for the nonrandom distribution. Although vessels from Duluth clustered at zone 36, this alone was not sufficient to reject the null hypothesis. The other ports exhibited no major clusters, partly because of a low sample size.

The results of this testing allow for the rejection of hypothesis 6 since in four out of five cases, the distributions were random and nonpatterned. There appears to be no relationship between the origin of vessels and spatial patterning of the resulting shipwrecks. The implication of these results may be that the Marquette--Sault Ste. Marie route is more conducive to patterning of loss in some way than the other transportation routes.

Hypothesis 7

This hypothesis postulates that there will be significant differences between the types of vessels used in the iron trade, grain trade, and coal trade. What is therefore expected is that different types of vessels will be associated with different commodities or will be used in varying frequencies. In order to confirm this hypothesis, it will be necessary to first establish that some vessel types are associated with particular commodity trades and then to evaluate

if these associations are different for each commodity and/or vessel type.

Test for Hypothesis 7

In the testing of this hypothesis, vessels were categorized by commodity and the differential frequencies of vessel types in each category were recorded. Five categories of vessels were recognized--schooners, schooner-barges, wooden steamers, steel steamers, and miscellaneous vessels. This last category was composed of a wide assortment of vessels, including propellers, iron and composite steamers, whalebacks, lumber hookers, etc. in order to create a category of sufficient size to undergo statistical analysis.

The breakdown by commodity and vessel type resulted in the creation of a contingency table with relative observed frequencies of vessels falling into each of the cells. Analysis using a contingency Chi Square test of association resulted in Table 41.

The Chi Square values in each cell illustrate the degree of association between the various elements. The summation of all Chi Square values resulted in a value of 19.21, which with eight degrees of freedom, is significant at the .05 level (15.5). This value is sufficient to reject the null hypothesis that "there is no association between commodity type and vessel." An association clearly exists between these two variables.

The X^2 values within each cell can be interpreted for a finer analysis of the association. The following relationships appear to be the most prominent:

Table 41. Results

Vessel Type	Iron			Grain			Coal		
	observed	expected	χ^2	observed	expected	χ^2	observed	expected	χ^2
Schooner	9	11.4	.51	3	5.3	1.00	10	5.3	4.17
Schooner- barge	18	13.5	1.50	2	6.3	2.93	6	6.3	.01
Wooden Steamer	15	19.1	.88	13	8.9	1.89	9	8.9	.00
Steel Steamer	17	16.0	.06	6	7.5	.30	8	7.5	.03
Miscellaneous Other	16	15.0	.07	11	7.0	2.29	2	7.0	3.57
TOTAL	75			35			35		
									145

1. schooners - coal
2. schooner-barges - grain, iron
3. wooden steamers - grain
4. steel steamers - equal for all commodities
5. miscellaneous vessels - grain, coal

Hypothesis 7 - Summary and Results

The results of the testing confirm hypothesis 7 because an association clearly exists between vessel types and certain commodity groups, and because this association is different for each group. The iron industry appears to lose proportionally higher numbers of schooner-barges; the grain trade loses a larger number of vessel types, including wooden steamers and miscellaneous vessels; and the coal trade primarily loses schooners. Fewer than expected deviations occur, with the grain trade using fewer schooner-barges and the coal trade fewer miscellaneous vessels.

Hypothesis 8

Hypothesis 8 states that shipwrecks will reflect the changes in vessel type that occurred over time. This proposition is very general and is open to several possible types of testing and interpretation. Implied in this statement is that relative frequencies of vessel types will change over time and that these changes will parallel those changes in vessel technology described in chapter 2. The general sequence of loss should approximate the sequence of development that is documented for the Great Lakes,

Test for Hypothesis 8

The test for this hypothesis will be accomplished through an analysis of the association between various vessel types and three periods of chronological development. Since this study is concerned with the period 1855-1930, three chronological segments of equal size (25 years each) were selected; period 1, 1855-1879; period 2, 1880-1904; and period 3, 1905-1930. Vessels were categorized within these three periods and by vessel type, and relative frequencies were tabulated from the data tables provided in Appendix B. The resulting contingency table was analyzed using a contingency Chi Square, with the results shown in Table 42. The cumulative χ^2 value of 81.81 is significant at the .005 level with eight degrees of freedom (22.0). But there are several problems with the analysis. The small sample size for period 1 (1855-1879) resulted in four expected values below five, which have a tendency to distort the tail of the distribution. This test also assumes that all vessel types would be represented in each period--which they were not. Steel steamers, for example, are known to have originated during period 2, which explains the zero observed frequency for this category during period 1. Given these problems, it is best to simply discuss the differing observed frequencies for each period and to de-emphasize the χ^2 results.

Hypothesis 8 - Summary and Results

Because of the unreliability of the χ^2 test, the interpretation of the test results must be based on the observed frequencies. During period 1, 13 of 21 (62 percent) vessels lost were schooners. Period 2 shows a predominance of schooner-barges (28 percent) and wood steamers

Table 42. Results

Vessel Type	Period 1			Period 2			Period 3		
	observed	expected	χ^2	observed	expected	χ^2	observed	expected	χ^2
Schooner	13	3.21	29.85	8	9.32	.19	1	9.47	7.58
Schooner- barge	3	3.79	.17	17	11.01	3.26	6	11.19	1.57
Wooden steamer	1	5.98	3.51	24	17.37	2.53	16	17.65	.15
Steel steamer	0	4.52	4.22	2	13.13	9.44	29	13.35	18.39
Miscellaneous vessels	4	3.50	.64	10	10.17	.003	10	10.33	.01
TOTAL	21			61			62		
									144

(39 percent), while steel steamers (47 percent) dominate period 3. These differences illustrate a chronological succession of losses comparable to the development of vessels discussed in chapter 2. In addition, a slight time lag is noted between the introduction of a new vessel type and the period of loss for that same type. The vessel data presented in Appendix B also illustrates this loss sequence. Based on this discussion, hypothesis 8 can be accepted because vessel loss reflects the changes in type that occurred over time.

Hypothesis 9

This hypothesis proposes that there will be significant differences in the extent to which iron, grain, and coal were affected by different types of loss. The four major types of loss--grounding, foundering, fire, and collision--should therefore be differentially associated with each of the commodities, and an association between commodity and loss type must be demonstrated to confirm this hypothesis.

Test for Hypothesis 9

In the testing of this hypothesis, vessels were categorized by commodity and loss type, and the frequencies of each were tabulated and placed into a contingency table. Overall, groundings and founderings were most frequent with 51 percent and 27 percent of all vessels respectively, followed by collisions and fire at 13 percent and 5 percent respectively. Because of the relatively small numbers of vessels in the last two categories, these were combined for analysis. A total of 136 vessels could be placed into one of the resulting nine cells of the table.

The contingency table created was then analyzed using the contingency Chi Square test, and X^2 values were obtained for each cell in the table. The results of that analysis are given in Table 43. The X^2 values of each cell illustrate the degree of association between the various attribute elements. As can be seen in Table 43, there are no associations of any substance within particular cells. The summation of X^2 values results in a value of 2.48, which is far less than the 9.49 needed for the .05 confidence level with four degrees of freedom.

So, there are no grounds for rejecting the null hypothesis that "there is no association between commodity type and type of loss."

Hypothesis 9 - Results and Summary

The results of the testing for hypothesis 9 demonstrate that the iron-, grain-, and coal-related vessels were not differentially affected by specific types of loss. Grounding, foundering, fire, and collision had approximately the same effect on each industry. Hypothesis 9 is therefore rejected because there was no demonstration of significant association.

Table 43. Results

Loss Type	Iron			Grain			Coal		
	observed	expected	χ^2	observed	expected	χ^2	observed	expected	χ^2
Grounding	34	38.1	.44	19	16.6	.35	20	18.3	.16
Foundering	21	19.8	.07	8	8.7	.06	9	9.5	.03
Collision/ Fire	16	13.1	.64	4	5.6	.46	5	6.3	.27
TOTAL	71			31			34		
								136	

Hypothesis 10

Hypothesis 10 states that there will be significant distributional differences between vessels of different loss categories. For example, vessels lost by grounding should be distributed differently from vessels lost by fire, collision, foundering—and so forth. In order to accept this hypothesis, it must be demonstrated that vessels of each loss category are nonrandom in their spatial distributions and that they are distributed in different patterns from one another.

Test for Hypothesis 10

Vessels were divided into four categories based on their condition of loss, and they were plotted onto a Poisson grid system for Lake Superior. The number of vessels occurring in each of the 65 cells were recorded, tabulated and placed in Appendix C, 10a-d. From these tables, the expected frequencies were calculated for analysis, using the Kolmogorov-Smirnov test for goodness of fit. Tables 44-47 illustrate the frequencies for each loss category.

Table 44. Grounding

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	36	20.50
1	15	23.66
2	6	13.65
3	2	5.25
4	2	1.52
5	0	.35
6	1	.07
7	1	.01
8	1	.002
9	0	-----
10	0	-----
11	0	-----
12	0	-----
13	1	-----

Table 45. Foundering

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	47	37.35
1	9	20.69
2	4	5.73
3	3	1.06
4	1	.15
5	0	.02
6	1	.002

Table 46. Collision

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	59	51.59
1	4	11.92
2	0	1.38
3	0	.11
4	1	.006
5	0	-----
6	0	-----
7	1	-----

Table 47. Fire

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	59	59.29
1	6	5.45

From these tables the mean, variance, CD, and D statistic were calculated within the results appearing in Table 48.

Table 48. Results

Loss Type	$\bar{x}$	s^2	CD	D
Grounding	1.154	4.930	4.272	.23846
Foundering	.554	1.293	2.335	.14846
Collision	.231	1.008	4.363	.11400
Fire	.092	.084	.916	.00400

The high variance and CD exhibited by the grounding category point to a nonrandom pattern. This is confirmed by the D value of .23846, which is significant at the .01 level (.19877). The values for the other three loss categories are not significant at the .05 level (.16567). Therefore, the null hypothesis that "loss types will be randomly distributed" is confirmed for foundering, collision, and fire, but rejected for grounding. The only patterned loss category is that of grounding.

Hypothesis 10 - Summary and Results

Based on the results of the Poisson test, hypothesis 10 is rejected because in three of four cases, the patterns are nonrandom. In the case of groundings (the most frequent type of loss), clustering of distributions occurred in zones 36, 54, 56, and 58. The former zone is particularly significant, with 13 losses within this area. Collisions appear to cluster in zones 44 and 59, while founderings occur most often in zone 58.

The fact that groundings are the most commonly occurring type of loss is significant because these are also highly patterned phenomena. The patterns of weather or local geography may make a major contribution to vessel loss in these areas. Vessels that must pass

these two points on a regular basis are therefore in greater danger of loss than vessels traveling by other routes.

Hypothesis 11

This hypothesis proposes that the frequencies of vessels in each loss category will vary by chronological period. That is, some loss types will associate with particular chronological periods, and those associations will change over time. In order to confirm this hypothesis, it would be necessary to demonstrate that an association exists and that the association changes over time.

Test for Hypothesis 11

The chronological period encompassed by this study covers the 75 years beginning in 1855 and ending in 1930. For the purpose of this test, this period was divided into three equal segments of 25 years each to form the following segments--1) 1855-1879, 2) 1880-1904, and 3) 1905-1929. Within each of these periods, the frequencies of vessels in each loss category were tabulated and placed in the cells of the created contingency table. The three general loss categories of groundings, foundering, and fire/collision were used as elements of the loss type attribute. Because of low frequencies of loss categories of loss through fire (seven for the entire 75 year period), this category was merged with the collision category for the purpose of testing.

The contingency table of frequencies was then analyzed using the contingency Chi Square test with the following results (Table 49).

Table 49. Results

[illegible]

The sum of the X^2 values of each cell resulted in a total value of 6.03, which was not significant at the .05 level with four degrees of freedom (9.49). Therefore, the null hypothesis that "there will be no association between chronological period and frequencies of losses in each loss type category" was accepted.

Hypothesis 11 - Summary and Results

Based on the results of the X^2 test, hypothesis 11 was rejected because no association between chronological period and loss type was found. Within each cell of the contingency table, three associations are of particular interest: fewer than expected groundings took place in period 2, more than expected founderingings occurred in period 2, and fewer than expected founderingings took place in period 3. None of these three associations were significant enough to influence the overall outcome of the test.

Hypothesis 12

This hypothesis posits that there will be an association between certain vessel types and the corresponding types of loss. For example, schooners may have been particularly susceptible to a particular type of loss, such as fire or grounding. The same can be said for each vessel type in the five general categories previously described in hypothesis 7. In order to confirm hypothesis 12, it is necessary to demonstrate that an association exists between vessel type and loss type and then to discuss the specific relationships between associated elements.

Test for Hypothesis 12

In testing this hypothesis, the attributes of vessel type and loss type were broken into their individual elements as was done in the previous hypotheses 7 and 9. This breakdown resulted in a 15-cell contingency table, onto which relative observed frequencies could be tabulated. After the computation of expected frequencies using the contingency X^2 method, the analysis was undertaken on each cell. Chi Square values were obtained and can be presented as follows in Table 50. The summation of X^2 values resulted in the overall X^2 value of 27.42, which is significant at the .005 level (23.60). This is grounds for the rejection of the null hypothesis "that no association exists between vessel type and loss type." Therefore, there is a strong association between these two attributes.

When individual cells are examined for their respective X^2 values, the reason for the strong association becomes apparent. The most significant association is seen between schooner-barges and foundering, with a X^2 value of 10.76. Other associations that can account for the strong association are between 1) schooner-barges and grounding, 2) steel steamers and foundering, 3) schooners and collision/fire, and 4) wooden steamers and collision/fire.

Table 50. Results

Vessel Type	Grounding			Foundering			Collision/Fire		
	observed	expected	χ^2	observed	expected	χ^2	observed	expected	χ^2
Schooner	16	11.9	1.41	5	6.1	.20	1	3.9	2.16
Schooner- barge	8	14.1	2.64	16	7.2	10.76	2	4.6	1.47
Wooden steamer	17	20.6	.63	10	10.6	.03	11	6.8	2.59
Steel steamer	21	16.3	1.36	4	8.4	2.30	5	5.4	.03
Miscellaneous vessels	14	13.0	.08	4	6.7	1.09	6	4.3	.67
TOTAL	76			39			25		
									140

Hypothesis 12 - Summary and Results

As previously stated, the strong association demonstrated through the testing process confirms hypothesis 12. The frequency of observed losses as compared to expected losses has also demonstrated that some vessel types are particularly prone to particular types of loss. To be specific, a large proportion of schooner-barges foundered relative to other types of loss. Wooden steamers were also more frequently lost through collision/fire than was expected. Other associations were less than expected, such as with schooner-barges and grounding, steel steamer and foundering, and schooners with collision/fire.

The relative lack of maneuverability for schooner-barges is one possible explanation for that association, since once a barge breaks tow (such as in a storm), it cannot navigate successfully on its own. The correlation of wooden steamers with fire and collision are potentially explained by the relative susceptibility of wooden vessels to fire. Their link to collisions remains a question at the present time.

Hypothesis 13

As stated, this hypothesis proposes that there will be significant distributional differences between vessels of different types. That is, schooners, schooner-barges, wooden steamers, steel steamers, and miscellaneous vessels will each exhibit nonrandom patterning. Additionally, if nonrandom patterns are found for each of these vessel types, it would also be expected that these patterns will differ from one another in their spatial distributions.

Test for Hypothesis 13

In order to test this hypothesis, the distributions of each vessel type were plotted onto the 65-cell grid for Poisson testing. Tables 13a-e in Appendix C present the frequencies obtained. Tables 51-55 illustrate the Poisson test.

Table 51. Schooner

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	56	47.76
1	4	14.71
2	3	2.27
3	1	.23
4	0	.02
5	0	.001
6	0	-----
7	1	-----

Table 52. Schooner-barge

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	50	42.92
1	9	17.81
2	5	3.70
3	0	.51
4	0	.05
5	0	.004
6	0	-----
7	0	-----
8	1	-----

Table 53. Wooden steamer

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	43	36.80
1	16	20.94
2	2	5.96
3	1	1.13
4	1	.16
5	2	.02

Table 54. Steel steamer

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	47	40.95
1	11	18.92
2	5	4.37
3	1	.67
4	0	.08
5	0	.007
6	1	-----

Table 55. Miscellaneous vessels

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	50	46.30
1	12	15.69
2	0	2.66
3	2	.30
4	1	.03

From these tables, the mean, variance, coefficient of dispersion, and D statistic were calculated with the following results.

Table 56. Results

Vessel Type	$\bar{x}$	s^2	CD	D
Schooner	.308	1.033	3.353	.12677
Schooner-barge	.415	1.258	3.031	.10892
Wooden steamer	.569	1.199	2.108	.09538
Steel steamer	.462	.626	1.355	.09307
Miscellaneous vessels	.339	.593	1.750	.05692

This table shows that the D values calculated are all well below the value needed to reject the null hypothesis that "the distribution of vessel types is random." For each vessel type, the spatial

distribution is random at the .05 level of significance (.16567).

Hypothesis 13 - Summary and Results

Hypothesis 13 is rejected based on the lack of nonrandom patterning for all vessel types. Although patterns were not significant in several cases, some clustering was noted in particular zones of the grid. For example, schooners often occurred in zone 54, schooner-barges in 58, wooden steamers in 58 and 59, and steel steamers in 36. This patterning is interesting but not statistically significant.

Hypothesis 14

This hypothesis proposes that there will be a direct relationship between the relative frequency of traffic vessels in each industry and the corresponding loss of those vessels for the same industries. That is, those industries with the greatest amount of traffic should have the highest rates of vessel loss and vice versa.

Test for Hypothesis 14

This hypothesis is very general and can be discussed through a simple comparison of traffic frequencies with loss frequencies. In order to accomplish this, the chronological period 1870-1910 was selected for scrutiny because these are the only years in which all three industries (iron, grain, and coal) were in simultaneous operation. Before 1870, the grain and coal industries were virtually nonexistent on Lake Superior, while after 1910, the frequency of vessel loss diminished to such a degree that frequencies are not comparable between industries.

For this 40 year period, the total combined tonnage of the respective commodities was tabulated based on the figures provided by

Williamson (1977:212-215, 234-235, 220-221)(see Appendix A). These commodity figures can then be interpreted in terms of relative frequency of traffic, assuming that vessel transportation capacities were the same for each industry. This assumption is not difficult to make since iron, grain, and coal were each bulk commodities and were transported by similar means. After the commodities were tabulated, the relative frequency of vessel loss for each corresponding industry was also tabulated using the data provided in Appendix B. The results can be seen in Table 57.

Table 57. Results

<u>Commodity</u>	<u>Tonnage</u>	<u>% Tonnage (traffic)</u>	<u>Vessel Losses</u>	<u>% Losses</u>
Iron	404,391,000	71	57	51
Grain	51,252,500	9	28	25
Coal	113,962,500	20	27	24

A comparison between the percent of traffic and the percent of losses shows that iron had nearly seven times more traffic than grain and more than triple that of coal, but had only double the losses of both grain and coal. On the other hand, grain had the least traffic but ranked second in total vessel losses. Coal, with 20 percent of the traffic and 24 percent of the losses, was the only commodity for which there was a rough correlation.

Hypothesis 14 - Summary and Results

Based on the comparison presented in hypothesis 14 is rejected since there is no direct correlation between frequency of traffic and frequency of loss for corresponding commodity groups. The figures seem

to indicate that iron-related vessels were lost at lower rates relative to frequency of traffic than other industries. Grain experienced high rates of loss in proportion to the amount of cargo transported.

Hypothesis 15

Hypothesis 15 states that there will be a direct association between the frequency of traffic in a given commodity from a given port and the associated frequency of vessels lost from that port. That is, if 50 percent of the iron industry traffic is from Marquette, then 50 percent of the losses would also be expected to be from Marquette.

Test for Hypothesis 15

The test for hypothesis 15 can be accomplished through the comparison of the relative traffic from Lake Superior ports and the associated loss from those same ports. Since the iron industry is the best recorded for production from each port, only this commodity will be investigated. As discussed in chapter 2, the ports of Duluth, Two Harbors, Ashland, and Marquette served as the major foci for the shipment of iron ore. The relative traffic from each port was calculated from the production figures of the respective areas by dividing the total yearly production from each port by the average yearly vessel capacity. This latter figure was obtained from sources discussed in chapter 3 for the average vessel capacity for certain period of time. An average was obtained on a yearly basis by incrementally increasing vessel capacity at an average rate. The annual vessel capacities for the period 1855-1920 are presented in Appendix C, Table 15.

The result of this traffic estimation was the conversion of production figures into traffic frequencies. These frequencies can

then be compared against vessel loss counts from respective ports tabulated from the data provided in Appendix B. Thus, the following figure for traffic and loss can be obtained.

Table 58. Traffic and loss

<u>Port</u>	<u>Number of Passages</u>	<u>Number of Losses</u>	<u>Number of Passages per single loss</u>
Marquette	24,663	25	987
Two Harbors	5,177	4	1,294
Ashland	13,521	11	1,229
Duluth	48,254	17	2,839

These figures indicate that for Marquette, Two Harbors, and Ashland there was an association between increased traffic and increased loss. In those cases, about one ship in 1,000 passages was lost. Duluth, on the other hand, was the anomalous figure, in that although it had the largest proportion of traffic, it had only approximately one loss per 3,000 passages--nearly one third the losses of the other three ports.

Hypothesis 15 - Summary and Results

On the basis of the comparisons, hypothesis 15 is rejected because a uniform association does not exist between traffic frequency and extent of loss from respective ports. The extremely small sample available for analysis may have had an impact on these results. In addition, there are many intervening variables that have an influence on the vessel loss counts, making them unreliable. For example, the four ports under consideration were not operating simultaneously. Marquette was the only ore-shipping port on Lake Superior for the period 1855-1884. In contrast, Duluth began ore shipments in 1892 when vessel technology

was safer and when vessel types (etc.) were different. Therefore, the data for testing this hypothesis was neither extensive nor comparable enough to determine a clear outcome to this traffic loss question.

Hypothesis 16

This hypothesis states that there will be no significant differences between salvaged vessels and nonsalvaged vessels in regard to vessel type. This means, for example, that schooners, schooner-barges, etc. should be salvaged at the same proportional rate.

Test for Hypothesis 16

In order to test this hypothesis, each vessel type was categorized into two classes--salvaged and nonsalvaged, or total loss. The number of vessels falling into these created categories were tabulated from Appendix B and then analyzed with a Kx2 Chi Square test. Table 59 presents these results.

Table 59. Results

<u>Vessel Type</u>	<u>Total Loss</u>	<u>Salvaged</u>	<u>Total</u>	<u>P</u>	<u>PA</u>
Schooner	16	6	22	.727	11.632
Schooner-barge	21	5	26	.808	16.968
Wooden steamer	31	6	37	.838	25.978
Steel steamer	12	19	31	.387	4.644
Propeller	4	3	7	.571	2.284
Composite steamer	3	0	3	1.000	3.000
Whaleback	4	3	7	.571	2.284
Miscellaneous vessels	8	4	12	.667	5.336
TOTAL	99	46	145		72.126

The Chi Square value derived from this test is 20.78, which is significant at the .005 level (20.3) with seven degrees of freedom. This is grounds for the rejection of the null hypothesis that "the ratio of

salvaged to nonsalvaged (total loss) vessels does not vary by more than chance from one vessel type to another."

Hypothesis 16 - Summary and Results

Because of the findings of the X^2 test, hypothesis 16 is rejected; the proportion of salvaged to nonsalvaged vessels does vary from one type to another. In particular, schooners and schooner-barges are less frequently salvaged than wooden steamers. In contrast, steel steamers are more frequently salvaged in comparison to other types. One explanation for this lies with the relative cost of the vessels to their salvage costs. Schooners and schooner-barges were cost-efficient vessels that were regarded as expendable after a few hard years of service. But steel steamers were very expensive vessels with a higher salvage value and would be salvaged more frequently.

Hypothesis 17

This hypothesis posits that there will be significant differences between salvaged and nonsalvaged vessels in regard to the port of origin (on the last voyage) of the respective vessels. In order for this hypothesis to be rejected, it would have to be demonstrated that salvage is undertaken at higher rates on vessels from some particular ports as compared to others.

Test for Hypothesis 17

Hypothesis 17 is not testable because of the differential recording of ports of origin for salvaged vessels. Only a small percentage of salvaged vessels had this attribute recorded, so comparisons could not be made. Had this information been available, the test could

have been easily completed using a format similar to that for hypothesis 16. Despite this lack of data, the basic hypothesis posed here is still quite relevant and may prove interesting if applied to another body of data.

Hypothesis 18

Hypothesis 18 states that there will be no significant differences between salvaged and nonsalvaged (total loss) vessels in regard to the month of their loss. Vessels lost in November, for example, should be salvaged at the same approximate rate as vessels lost in July.

Test for Hypothesis 18

Using the data from Appendix B, each vessel was categorized by salvaged versus nonsalvaged and the month of loss. Frequency distributions were tabulated and a Kx2 Chi Square analysis completed. Table 60 presents these results.

Table 60. Results

<u>Month</u>	<u>Total Loss</u>	<u>Salvage</u>	<u>Total</u>	<u>P</u>	<u>PA</u>
January	0	0	0	0.000	0.000
February	0	0	0	0.000	0.000
March	0	0	0	0.000	0.000
April	1	1	2	.500	.500
May	6	5	11	.545	3.270
June	5	5	10	.500	2.500
July	5	2	7	.714	3.570
August	5	4	9	.556	2.780
September	22	4	26	.846	18.612
October	22	10	32	.688	15.136
November	29	15	44	.659	19.111
December	3	0	3	1.000	3.000

The Chi Square value derived from this test is 8.023, which is not significant at the .05 level with 11 degrees of freedom (19.7). Even with the elimination of the January through March months when navigation is closed, the test is still not significant with eight degrees of freedom (15.5) at the .05 level. The null hypothesis that "the ratio of salvage to nonsalvage vessels does not vary by more than chance by month of loss" is accepted.

Hypothesis 18 - Summary and Results

The acceptance of the null hypothesis results in the acceptance of hypothesis 18. There is a slight tendency for vessels lost in September to be salvaged at a lower rate, but this is certainly not statistically significant.

Hypothesis 19

This hypothesis states that there will be no significant distributional differences between salvaged and nonsalvaged vessels for each commodity and for all shipwrecks lost on Lake Superior. That is, salvage should be uniform for all three industries and should be spatially distributed in the same manner for salvaged as for nonsalvaged vessels. In addition, it would be expected that there would be no significant difference between the distribution of all total losses (nonsalvaged).

In order to reject this hypothesis, it would be necessary to demonstrate that all three industries have a nonrandomly patterned distribution and that these patterns are unequal in distribution. Likewise, both salvaged and nonsalvaged distributions for all three industries combined should be nonrandom and differentially patterned.

Test for Hypothesis 19

In order to test this hypothesis, it was necessary to divide vessels into six major categories.

- 1) Iron - total loss
- 2) Iron - salvaged
- 3) Grain - total loss
- 4) Grain - salvaged
- 5) Coal - total loss
- 6) Coal - salvaged

In addition, two other categories--7) all commodities total loss, and 8) all commodities salvaged--were created from the six previous groupings. These eight categories of vessels were then plotted onto the Poisson grid system and differential wreck frequencies were tabulated. These appear in Appendix C, Tables 19a-h. Using these frequencies, expected frequencies were calculated for each. The results are as follows.

Table 61. Iron - total loss

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	48	32.53
1	9	22.51
2	3	7.79
3	2	1.81
4	0	.31
5	0	.04
6	1	.005
7	1	-----
8	0	-----
9	0	-----
10	0	-----
11	1	-----

Table 62. Iron - salvaged

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	52	44.23
1	8	17.03
2	2	3.28
3	2	.42
4	0	.04
5	0	.003
6	0	-----
7	1	-----

Table 63. Grain - total loss

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	47	45.61
1	15	16.15
2	1	2.86
3	2	.34

Table 64. Grain - salvaged

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	57	56.57
1	7	7.86
2	1	.55

Table 65. Coal - total loss

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	51	47.07
1	9	15.20
2	3	2.46
3	2	.26

Table 66. Coal - salvaged

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	57	54.03
1	5	10.00
2	2	.93
3	1	.06

Table 67. All commodities - total loss

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	34	16.52
1	16	22.63
2	7	15.50
3	1	7.08
4	1	2.42
5	0	.66
6	2	.15
7	2	.03
8	0	.005
9	0	.0008
10	0	-----
11	1	-----
12	0	-----
13	0	-----
14	0	-----
15	1	-----

Table 68. All commodities - salvaged

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	44	31.96
1	11	22.69
2	5	8.05
3	1	1.91
4	2	.34
5	0	.05
6	1	.006
7	0	.001
8	1	-----

From these tables, the mean variance, coefficient of dispersion, and D statistic were calculated with Table 69 providing the summary results.

Table 69. Results

<u>Commodity</u>	<u>$\bar{x}$</u>	<u>s^2</u>	<u>CD</u>	<u>D</u>
Iron-total loss	.692	3.290	4.750	.23800
Iron-salvage	.385	1.129	2.932	.11954
Grain-total loss	.354	.444	1.254	.02138
Grain-salvage	.139	.150	1.077	.00661
Coal-total loss	.323	.495	1.533	.06123
Coal-salvage	.185	.304	1.644	.04570
All vessels-total loss	1.137	7.128	5.230	.26892
All vessels-salvage	.710	2.148	3.03	.18523

This table indicates that only three of the eight categories are significant at the .05 level (.16567) and that there are grounds for rejecting the null hypothesis, which states that "the distributions of vessels in each category are randomly distributed." Category 1 (Iron - total), category 7 (all vessels - total), and category 8 (all vessels - salvage) are the only groups found to have distributions that are nonrandom.

Tables 19a-h, Appendix C indicate the frequency of wrecks found in each cell. For each category, some clustering can be noted, but it is significant only in the three categories. The zones of most frequent occurrence for each of these three categories are:

1. Iron - total: 56, 58, 59
2. All vessels - total: 36, 54, 56, 57, 58, 59
3. All vessels - salvage: 36, 54

Hypothesis 19 - Summary and Results

Because nonrandom patterns were detected in three of the eight categories and because salvage was not uniform across all three industries under consideration, this hypothesis can be rejected. The iron industry was patterned in the distribution of wrecks that were not salvaged, while both general categories of vessels (salvage and non-salvage) were likewise patterned. The grain and coal trades are both randomly patterned for both categories within each commodity. The results tend to indicate that salvage was randomly undertaken in regard to all three industries under evaluation.

Hypothesis 20

According to this hypothesis, there will be no significant differences between salvaged and nonsalvaged vessels with regard to the type of loss that brought about the respective shipwreck. For example, vessels lost by grounding would be salvaged at the same rate and in the same pattern as the vessels lost by foundering. To reject this hypothesis, it must be demonstrated that particular types of loss are associated with higher rates of salvage than others.

Test for Hypothesis 20

The four major types of loss--collision, fire, grounding and foundering--were divided into categories based on whether they were salvaged or not salvaged (total loss). The resulting eight combinations were then tested by the Kx2 Chi Square method, with results as seen in Table 70.

Table 70. Results

<u>Loss Type</u>	<u>Total Loss</u>	<u>Salvage</u>	<u>Total</u>	<u>P</u>	<u>PA</u>
Collision	14	4	18	.778	10.892
Fire	4	3	7	.571	2.284
Grounding	39	34	73	.534	20.826
Foundering	35	3	38	.921	32.235
TOTAL	92	44	136		66.237

The Chi Square value for this test was 18.47, which is significant at the .005 level with three degrees of freedom (12.8). Based on this value, the null hypothesis that "the ratio of salvaged to nonsalvaged vessels does not vary by more than chance in relation to the type of vessel loss" was rejected. There is strong association between some types of vessel loss and the degree to which they were salvaged.

Hypothesis 20 - Summary and Results

Based on this test, hypothesis 20 is rejected because there are significant differences in the degree to which some loss types were salvaged. In particular, groundings were salvaged at a much higher rate than other loss types, while founderings were salvaged at a very low rate. Collisions were also not salvaged as often, and those vessels lost by fire were salvaged approximately equally. One explanation for these results lies with the high degree of effort and cost needed to salvage vessels from deep water as opposed to those lost in shallower water. Groundings are relatively easy to salvage as opposed to founderings and collisions, which often occur in deep water and are thus less likely to be raised.

Hypothesis 21

Hypothesis 21 proposes that there will be no significant differences in regard to the frequency of salvage between vessels of the three commodities of iron, grain, and coal. For example, vessels of the iron industry would be expected to be salvaged at the same rates as vessels in either the grain or coal trade.

Test for Hypothesis 21

Lake Superior shipwrecks were categorized by their respective industry affiliations and by their status as total losses or salvaged losses. The resulting six categories were used to tabulate frequencies from data provided in Appendix B, and the following table was created and analyzed using the Kx2 Chi Square test.

Table 71. Results

<u>Commodity</u>	<u>Total Loss</u>	<u>Salvage</u>	<u>Total</u>	<u>P</u>	<u>PA</u>
Iron	50	23	73	.685	34.250
Grain	26	9	35	.743	19.318
Coal	23	12	35	.657	15.111
TOTAL	99	44	143		68.679

The Chi Square value of .803 was not found to be significant at the .05 level with two degrees of freedom (5.99). Therefore, the null hypothesis that "the ratio of salvaged to nonsalvaged vessels does not vary by more than chance from one commodity category to another" is accepted.

Hypothesis 21 - Summary and Results

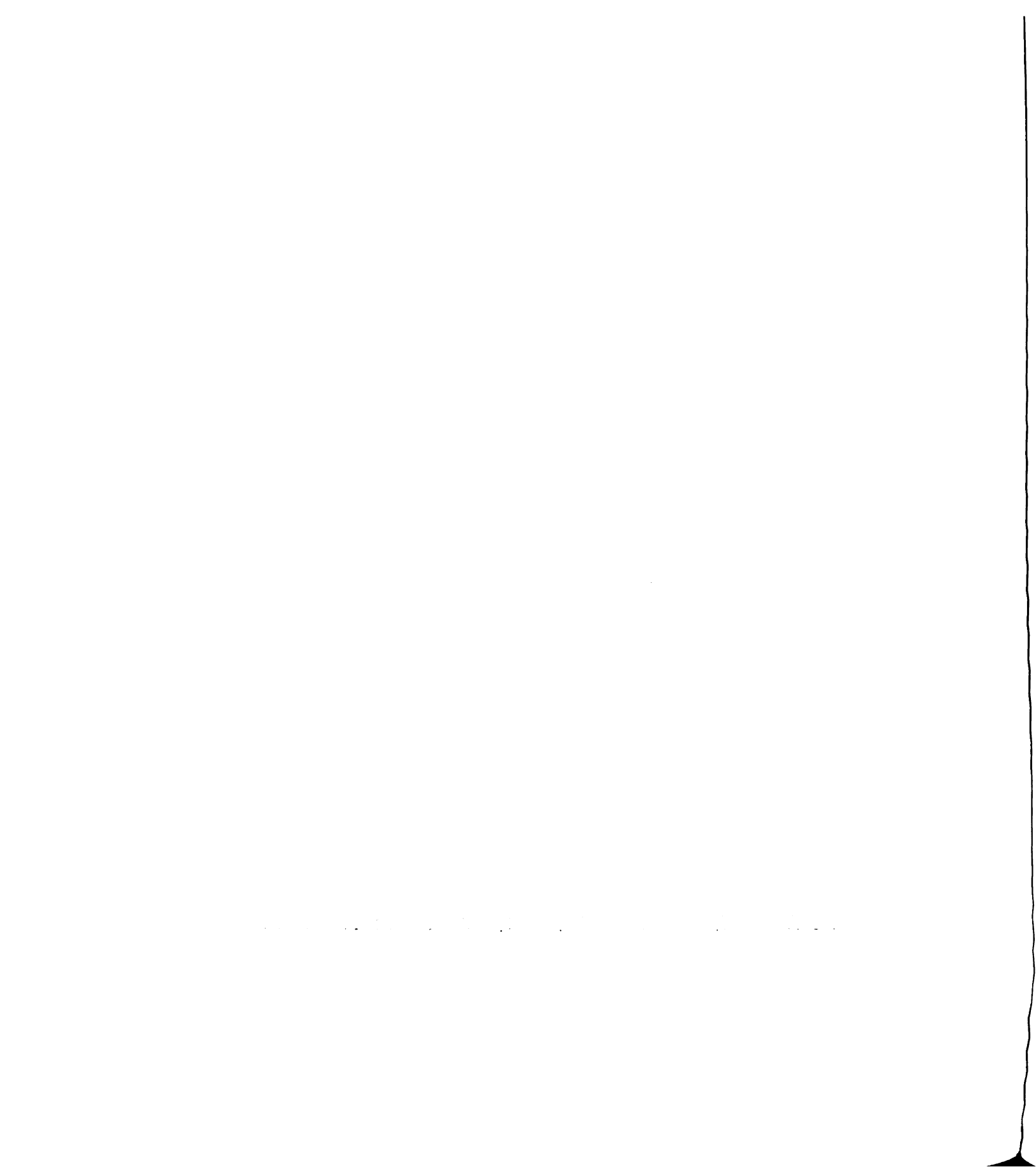
Based on the results of the χ^2 test, hypothesis 21 was accepted because there are no differences in the frequency of salvage between the three commodities in question. There was a slight tendency for grain trade vessels to be salvaged at a lower rate than iron or coal (35 percent of the time compared with 46 percent and 52 percent) but this was not significant enough to statistically demonstrate an association. The rapid spoilage of grain after water contamination is a likely explanation for this tendency.

Summary of Results

This chapter focused on the testing of the hypotheses presented in chapter 4. Of the 21 hypotheses presented, only 19 could be tested using the available data. Two hypotheses were untestable because of limitations in recorded data or because of small sample sizes not conducive to analysis. The 19 hypotheses that were tested have provided much information on the associations between the numerous variables under investigation. This summary section will outline the major variables that were tested, along with the general results of the analysis for each.

Shipwreck Location

This factor is the most important in understanding the spatial distribution of shipwrecks across Lake Superior. Seven hypotheses dealt directly with locational data—hypotheses 1, 2, 3, 6, 10, 13, 17, and 19. Of these, hypotheses 3 and 17 were untestable. The remaining hypotheses were tested and revealed that:



1. Shipwrecks in general are highly patterned in a nonrandom fashion--Hypothesis 1.
2. Only vessels from the iron industry are nonrandomly patterned; coal and grain related vessels are not--Hypothesis 1.
3. Shipwrecks in general are nonrandomly patterned for the period 1880-1904, but are randomly patterned for the periods 1855-1879 and 1905-1929--Hypothesis 2.
4. Iron industry vessels from Marquette are nonrandomly patterned, but vessels from Duluth, Two Harbors, and Ashland are not--Hypothesis 6.
5. Vessels lost through grounding are nonrandomly patterned, while vessels lost by foundering, fire, and collision are randomly patterned--Hypothesis 10.
6. Vessels of specific types are all randomly patterned--Hypothesis 13.
7. In general, salvage was spatially patterned in a nonrandom fashion.

Commodity Affiliation

Vessels of the iron, grain, and coal industries were hypothesized to have characteristics that set them apart from one another in relation to other variables. These relationships were explored by hypotheses 1, 2, 3, 4, 5, 7, 9, 14, 15, and 21. Of these, 1, 2 and 3 have been discussed as they relate to shipwreck location and will not be further elaborated on. The results of the other hypotheses are as follows:

1. For all three industries, there was a direct correlation between the length of the navigational season and the frequency of loss--Hypothesis 4.
2. Vessels affiliated with each commodity were affected differently by storms. Grain shipwrecks experienced 80 percent loss due to storms, coal 66 percent, and iron 48 percent--Hypothesis 7.
3. Some commodities lost higher frequencies of some vessel types than others. Iron lost more schooner-barges, grain more wooden steamers and miscellaneous vessels, and coal more schooners and miscellaneous vessels--Hypothesis 7.

4. All commodities were equally affected by groundings, founderings, fire, and collision--Hypothesis 9.
5. Iron industry vessels were lost at a lower rate relative to traffic, while grain was lost at a higher rate in proportion to traffic than either iron or coal--Hypothesis 14.
6. There is no clear correlation between frequency of traffic from a given port and corresponding losses from that port--Hypothesis 15.
7. Vessels associated with each of the three commodities were salvaged at approximately the same rate--Hypothesis 21.

Vessel Type

The types of vessels lost on Lake Superior are interrelated with many other variables and constitute a major element for analysis in this study. Six hypotheses touch on vessel type in some manner--7, 8, 12, 13, and 16. Of these, 7 and 13 have been discussed in the previous results as they relate to location and commodity affiliation. The results of testing for the others are as follows.

1. The chronological sequence of vessel types lost on Lake Superior correspond with documented historic sequences with a slight time lag indicated--Hypothesis 8.
2. An association was found between certain vessel types and corresponding specific types of loss. Schooner-barges were linked to foundering, and wooden steamers to collision/fire--Hypothesis 12.
3. Some vessel types were salvaged at a higher rate than other types. Schooners and schooner-barges were salvaged less, and steel steamers were salvaged at significantly higher rates--Hypothesis 16.

Loss Type

Four specific types of vessel loss apply to Lake Superior shipwrecks--groundings, founderings, collision, and fire. The variable of loss type interrelates with numerous other variables and has been included in five hypotheses--9, 10, 11, 12, and 20. While hypotheses

9, 10, and 12 have already been discussed in relation to previous variables, the results of 11 and 20 are as follows.

1. Loss types did not significantly vary over time--Hypothesis 11.
2. Differences were found between salvaged and nonsalvaged vessels in regard to the type of losses that brought about respective shipwrecks. Groundings were salvaged most often, while collisions and founderings were salvaged least.

Salvaged/Nonsalvaged

The element of salvage is basic to the understanding of Type B transforms discussed in this study. Once a vessel is deposited on the lake bottom, a number of factors affect whether the vessel becomes part of the archaeological record. Salvage is one cultural variable that has a major effect on this process. Six hypotheses relate salvage to other shipwreck variables--16, 17, 18, 19, 20, and 21. Of these, only 18 has not been discussed elsewhere in this summary. The result of hypothesis 18 is:

1. There is no difference in salvage by the month in which vessels were lost--Hypothesis 18.

Other Variables

A number of other variables have been discussed in relation to the hypotheses presented in this chapter. Since all of these have been discussed in relation to the five more prominent variables (location, industry, vessel type, loss type, salvage), they will not be further elaborated upon. However, the following listing of variables with their associated hypotheses are provided as an easy cross reference to related attributes.

1. Port of origin - Hypotheses 6, 17
2. Date of loss - Hypotheses 8, 11, 18
3. Frequency of traffic - Hypotheses 14, 15
4. Frequency of storms - Hypothesis 5
5. Length of navigational season - Hypothesis 4

CHAPTER VII

INTERPRETATION AND CONCLUSIONS

Interpretation of Results

The broader goal of this study is to investigate the formative process of the archaeological record as it applies to the question of the spatial representativeness of Lake Superior shipwrecks. Therefore, the interpretation of the results obtained through the process of hypothesis testing should likewise be directed toward these broader issues. The patterning of vessels noted in the previous chapter will be discussed as it relates to these questions, and a descriptive model will be generated to provide a detailed explanation for the nonrandom distributions that were found.

The testing phase of this project resulted in the definition of three major spatial distributions of particular relevance: 1) iron industry vessels are spatially nonrandom in distribution; 2) within the iron industry, vessels from the port of Marquette are particularly nonrandomly patterned; and 3) salvage was undertaken in a spatially nonrandom manner. Each of these results has an important bearing on the understanding of the mechanisms of deposition and decomposition that ultimately result in the formation of the archaeological record. The Type A and Type B transforms that are the active ingredients of this process will be discussed in the following sections.

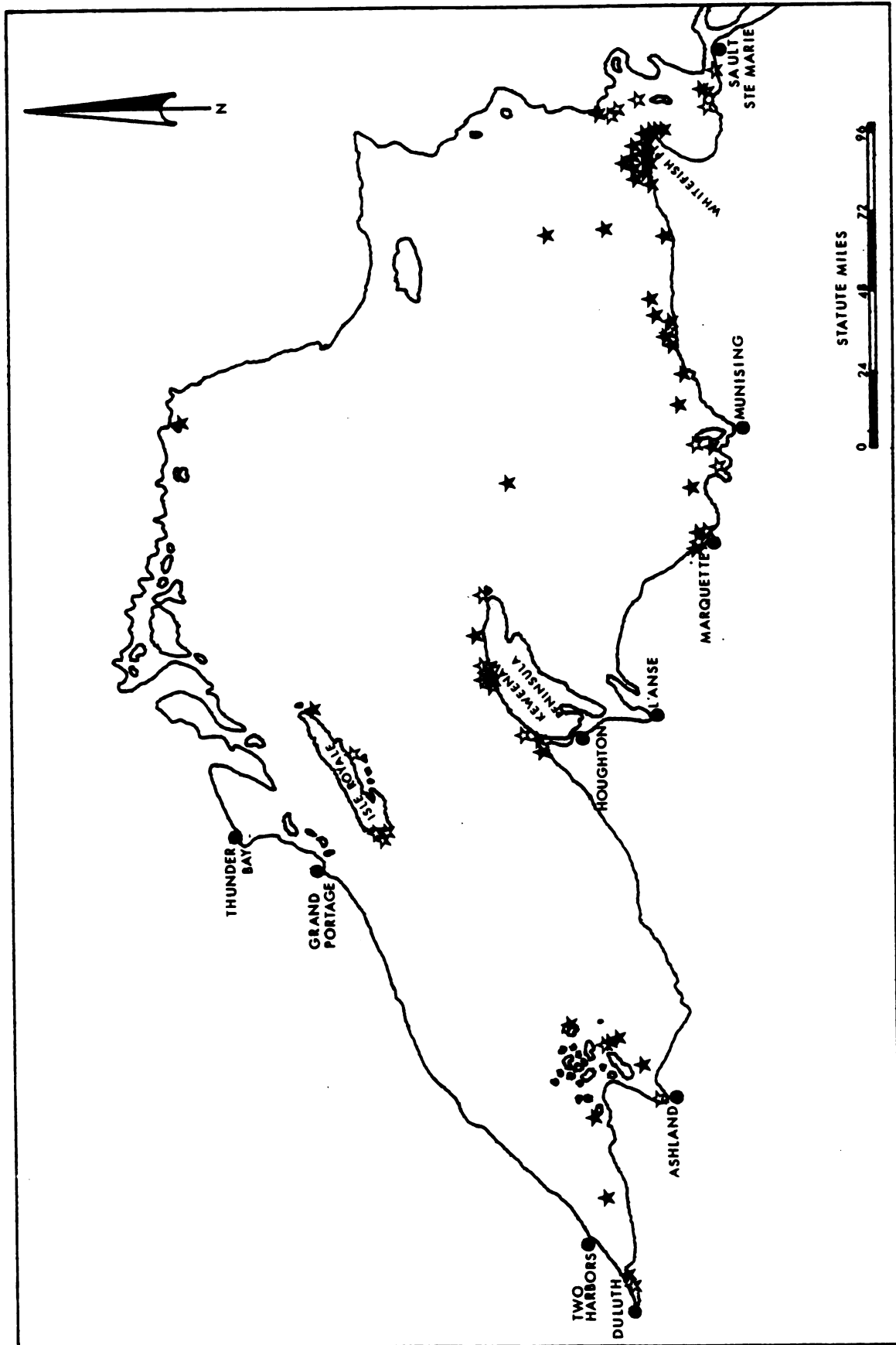
Type A: Depositional Transforms

The cultural and noncultural variables that result in the initial deposition of Great Lakes shipwrecks into the archaeological record are dealt with in Hypotheses 1 through 15. These hypotheses provide insights into the formative process of the Great Lakes shipwreck record by testing the relationship between the variables responsible for vessel loss. The spatial patterns noted for the iron industry thus have their explanation at least in part from the results of the associations noted in chapter 6. To provide an explanation for the nonrandom patterns of iron-related vessels and the random patterns of coal and grain, a brief review of the other hypotheses results is needed. The major questions to be answered in this regard are

- 1) Why are iron vessels spatially patterned while coal and grain are not? and
- 2) Why do iron vessels pattern along the Marquette-Sault Ste. Marie route and not along the other routes?

The main differences between iron industry vessel distributions as opposed to grain and coal patterns is that the former are tightly clustered in two main areas--the western tip of the Keweenaw Peninsula between Eagle River and Copper Harbor, and the area of western Whitefish Point east of Deer Park. Also, smaller clusters of wrecks occur at Marquette, Grand Island, and Au Sable Point (see Figure 13). Of the 75 total iron affiliated vessels lost between 1855 and 1920, only one was located on the north shore of Lake Superior. Five other vessels were lost on the south side of Isle Royale, four of which were later salvaged. Along the area from Marquette to Sault Ste. Marie, a scatter of lost vessels accounted for a large proportion of the total vessels lost on the lake.

Figure 13. Iron-related shipwreck distributions



In contrast, the pattern of grain losses was significantly different in many respects (see Figure 14). First, seven of 35 (20 percent) vessels were lost on the north shore, while several others were lost in open water at various points across the lake. Generally, grain affiliated vessels have a very dispersed pattern and appear to be scattered across a major portion of the lake, as opposed to iron vessels, which were primarily deposited close to shore (as groundings); that is, a higher proportion of grain vessels were lost in open water. Approximately the same frequency of grain vessels as iron industry vessels were lost along the southern Isle Royale coast and if grouped collectively, they constitute the only recognizable cluster of grain wrecks on the lake.

As Figure 15 illustrates, the pattern of coal losses is somewhere between that of iron and grain. While the pattern is dispersed in contrast to iron, small clusters of wrecks occur in several areas. The largest of these clusters is the area surrounding Marquette Harbor, with five losses of 35 total occurring in this locality. There is also a scattering of vessels between Marquette and Sault Ste. Marie, but no major clusters of wrecks occur at Au Sable or Whitefish Points as was the case for iron. Three coal vessels were lost along the north shore of the lake, no vessels were lost at Isle Royale, and only one was lost on the Keweenaw Peninsula north of the ship canal.

Obviously, each commodity displays a significantly different pattern ranging from nonrandom/clustered for iron to random/clustered for coal to random/dispersed for grain. The Poisson tests performed upon these commodity distributions in Hypothesis 1 confirmed these patterns. What remains in question is the causal factors behind these

Figure 14. Grain-related shipwreck distributions

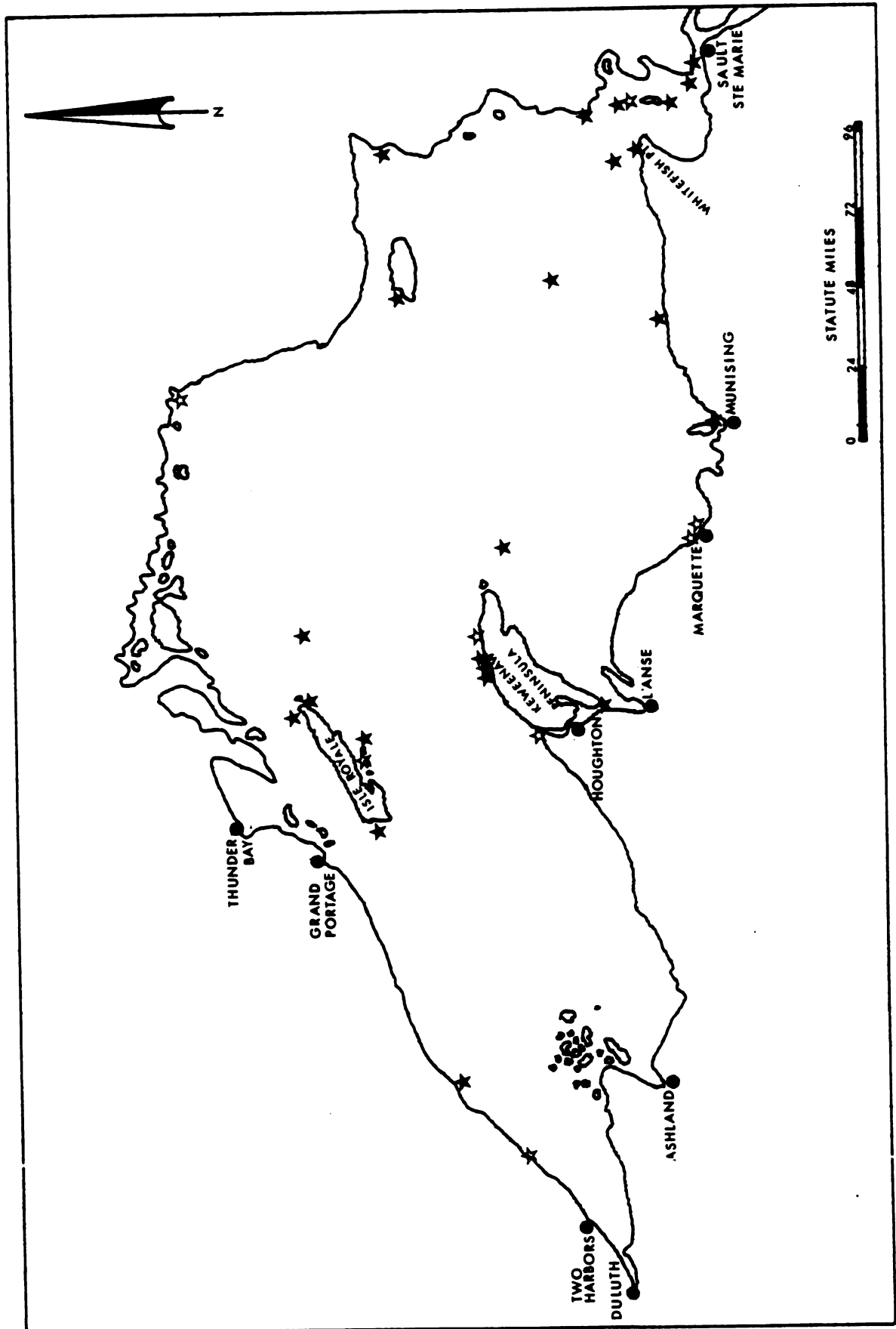
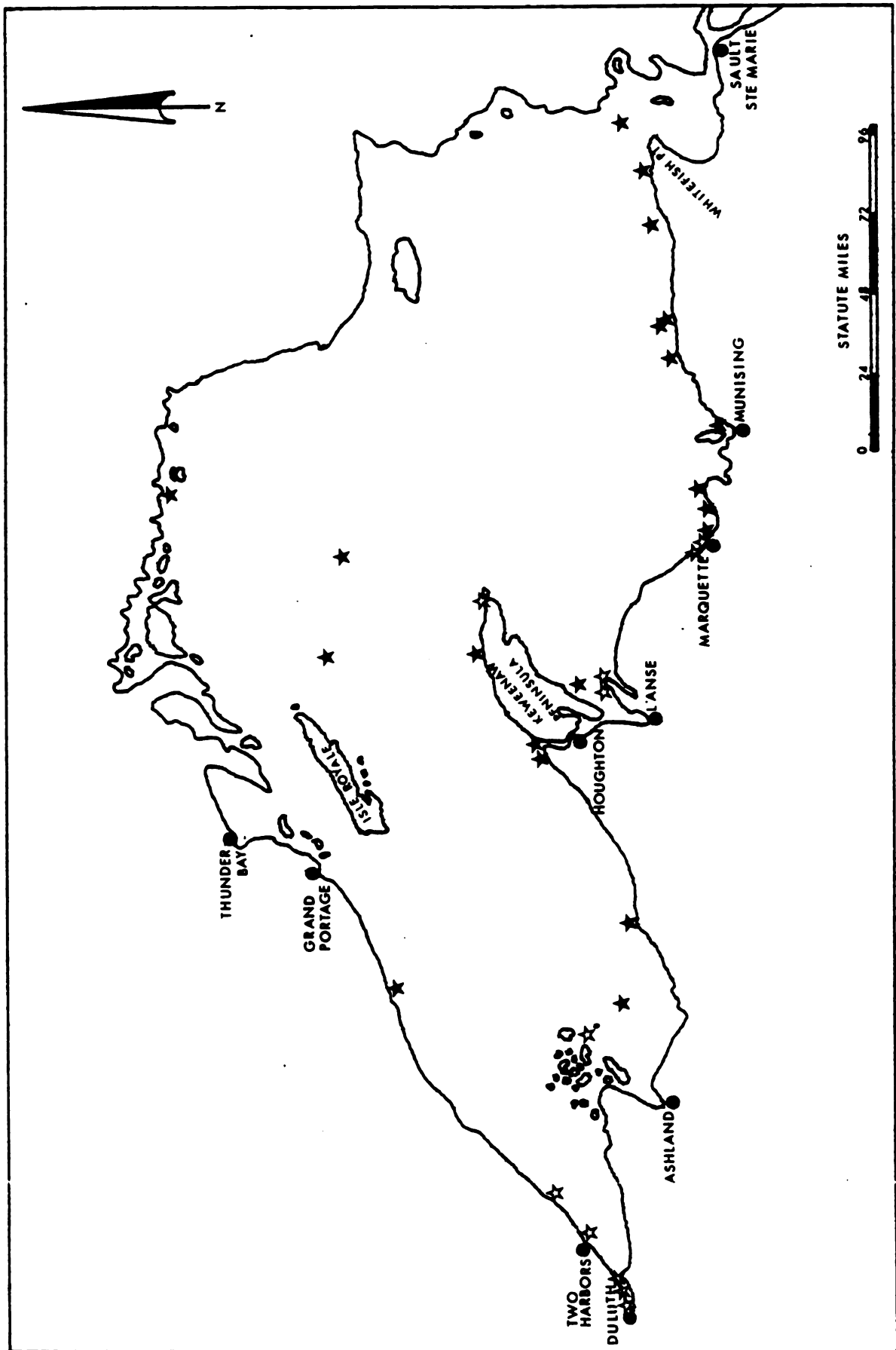


Figure 15. Coal-related shipwreck distributions



distinctive spatial arrangements. Through the results of the hypotheses tested in chapter 6, the interpretation of these patterns can be accomplished to some extent. For example, the dispersed nature of grain-related vessels could be explained by the significantly higher percentage of loss due to storms for that industry. It is very possible that storms have a dispersing effect on distributions by blowing vessels far off course. Travel routes requiring vessels to be far from land would particularly be susceptible to these effects since vessels would not have the option of running for port or attempting an intentional grounding in an easily salvaged area. Because grain trade vessels were primarily from Duluth and Port Arthur, both of these transportation routes would require a large percentage of open water sailing. When on open water, the rapidly rising storms of Lake Superior can often catch vessels unaware and unprepared. Riding out these storms often required leaving course and following the most expedient route to safety. The high frequency of fall month storms would exacerbate this problem because this was the peak time of travel for grain vessels. Table 72 illustrates the relative percentages of vessels lost in the months of October and November, when fall storms are at their highest frequency.

Table 72. Percentage of vessels lost in October and November

<u>Commodity</u>	<u>Oct. & Nov. of Losses</u>	<u>of Total Losses</u>	<u>% of Vessels Lost in Oct. & Nov.</u>	<u>Total % Loss Due to Storms</u>
Iron	18	75	24	48
Grain	20	35	57	80
Coal	13	35	37	66



As can be seen from this table (tabulated from Appendix B data), grain-related vessels were lost at a much higher frequency in the fall months of navigation than either iron or coal. Coal was second in number of losses, possibly because of the higher fall traffic needed to stockpile coal for winter heating. Iron-related vessels were least affected in these months, which may help explain their similar lower frequency of storm losses.

If storms are actually the major cause for dispersed patterning of Lake Superior vessels, then it would be expected that given the percentage of losses due to storms, iron should be least dispersed, grain most dispersed, and coal somewhere in between. This hypothesized distribution is identical to the types of patterning previously described for respective commodity-related vessels. In order to test the proposition that storms disperse vessel distributions, four Poisson tests were performed to determine if patterning is random. Given the respective percentages of loss by storms for each commodity group (iron 48 percent, grain 80 percent, coal 66 percent), it would then be expected that grain should be most dispersed, coal should be somewhat less dispersed, and iron should be least dispersed. And if storms are randomizing phenomena, then all three industries should be distributed in accordance with the extent to which each are differentially affected by storms. Appendix C contains the frequency counts for these Poisson tests. The observed and expected frequencies tabulated from the frequency counts are as follows.

Table 73. Iron - storms

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	49	38.50
1	7	20.20
2	6	5.30
3	2	.92
4	0	.12
5	0	.01
6	0	-----
7	0	-----
8	0	-----
9	1	-----

Table 74. Grain - storms

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	47	47.05
1	14	15.20
2	3	2.46
3	0	.26
4	1	.02

Table 75. Coal - storms

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	50	48.54
1	10	14.17
2	4	2.07
3	0	.20
4	0	.02
5	1	-----

Table 76. All commodities - storms

<u>number of wrecks/cell</u>	<u>observed frequencies</u>	<u>expected frequencies</u>
0	34	18.10
1	13	23.10
2	6	14.80
3	7	6.30
4	1	2.00
5	1	.52
6	0	.11
7	1	.02
8	0	-----
9	0	-----
10	1	-----
11	1	-----

A summary of the goodness of fit, variance, and coefficient of dispersion for these four tests is shown in Table 77.

Table 77. Summary

Category	$\bar{x}$	s^2	CD	D
Iron	.523	1.727	3.302	.1615
Grain	.323	.509	1.576	.0269
Coal	.292	.663	2.271	.0417
All vessels	1.280	4.690	3.670	.2446

At the .05 confidence level (.1657), only the combined distribution for all vessels is patterned nonrandomly. Each individual commodity is therefore randomly patterned as would be expected if storms exhibited a randomizing effect on vessel distribution. The figures in Table 77 also illustrate that iron-related vessels are least randomly affected by storms, while grain-related vessels are most dispersed in their pattern but not to the same extent. There is direct association between iron-carrying vessels and a more clustered but random distribution, and

grain-related vessels and a very dispersed distribution. Given that 80 percent of all grain shipwrecks are storm related, it is not surprising that overall grain vessel distributions are random. In contrast, iron industry related vessels are least affected by storms and exhibit the most clustering in storm-related accidents. A major clustering of these vessels was encountered for zone 58 (Whitefish Point), which indicates a higher frequency of loss in this area for iron related wrecks.

Of the four Poisson tests conducted, the combined category resulted in a nonrandom pattern. This shows that the overall patterning of vessels in storm-related accidents are nonrandom, with clustering occurring in zones 35, 36, 54, and 58. The entire western edge of the Keweenaw Peninsula, the Marquette area, and Whitefish Point were collecting areas for vessels lost in storms. These results imply that since most storms come from the west and northwest, the highest concentrations of lost vessels will be in areas on the windward side of the storm path. Conversely, few vessels were lost on the leeward side of land because they would have been in protected waters. Whitefish Bay west of Sault Ste. Marie is an example of this. As hypothesis 1 has shown, the highest losses on Lake Superior (15) occurred in zone 59--Whitefish Bay. Of these losses, only three (20 percent) were a result of storm conditions. In contrast, the windward face of Whitefish Point (zone 58) had a similar 15 total losses but 11 of these (73 percent) were caused by storm activity. Clearly, those routes following the most windward stretches of water run the highest risk of loss due to storms.

The randomizing effects of storms may also have had a greater impact on some vessel types than on others. Generally speaking, the more sizable and modern the vessel, the better the chance it would have of either avoiding storms (because of modern weather communication) or riding out the storms while maintaining vessel course. For example, modern ore boats regularly faced fall storms with fatalities such as the Edmund Fitzgerald, an extreme rarity. As vessel size gradually increased over time, the ability of vessels to weather the storms of Lake Superior also increased. It is not surprising therefore that hypothesis 7 illustrates a much higher frequency of loss for smaller vessel types--schooners and schooner-barges--than for larger types such as steel steamers. Hypothesis 8 reveals a similar trend; for each chronological period under consideration, particular types of vessels were lost in varying proportions. The period before 1905, when both sailing vessels and larger steam powered vessels were in competition on the lake, also was the time when significantly higher numbers of sailing craft were lost. Schooners and schooner-barges were lost at much higher rates than the more modern and costly steel steamers. This cost factor is especially important to an understanding of the storm randomization process.

As discussed in chapter 3, the iron, grain, and coal trades varied substantially in capital intensity. Iron in particular was the most significant industry on Lake Superior with total transportation for 1870-1910 being four times that of coal and eight times that of grain for the same period, as pointed out in hypothesis 14. Initial investment into the iron industry by wealthy eastern entrepreneurs and later investment by large national conglomerates such as US Steel helped

to build the industry from a small pick and shovel operation in 1850 to the premier example of capitalistic endeavor by 1900. Throughout this process, the availability of tremendous amounts of capital for expansion and improvements has been a significant factor in rapid development. As pointed out by several authors, (Hatcher 1950), (Barry 1974), (Evans 1942), this financial capacity enabled the iron industry to create and maintain the largest and most modern fleet of vessels on the Great Lakes for the period under study. As new innovations in vessel technology were discovered, the iron industry soon adapted them to their fleets. As a newer and larger vessel was designed, one of the major iron companies soon purchased it for use in the Lake Superior ore trade. Technological innovation followed the lines of highest capital intensity with the wealthiest companies and industries receiving modern improvements before others of lesser financial ability. This process allowed the iron industry to maintain a large modern fleet, while smaller industries relied more upon slightly older and less modern vessels. When steel and iron steamers first came into use in the 1870s and 1880s, it was the iron industry that first adopted them (Barry 1974:145-188). This was true for the majority of new bulk carriers that were introduced throughout the period. As iron fleets were updated, older vessels were scrapped and sold when their economic efficiency dipped below desired standards.

Compared to the modern and wealthy iron industry, the transportation of grain was a poor competitor. The grain trade per se was not an industry in the strict sense of the word. Rather, it was a process by which grain was centralized in certain ports for shipment to other regions. Grain was moved under contract between the purchasers of the

cargo and the independent vessel owners or shipping companies. Although the grain trade was by no means simple in technology or transportation, it was not as centralized as the iron industry, hence technological improvements came more slowly. The decentralized nature of the grain trade influenced its ability to make uniform capital improvements in the fleets and as a result, grain fleets on the whole lagged behind iron fleets in vessel size and modernization. Smaller, less modern vessels would, therefore, be more susceptible to loss by storms, hence the higher loss rate.

The movement of coal was also not a true industry but a commodity marketing system similar in many respects to that of grain. The main difference between coal and the other two commodities is that it moved upbound as a return cargo for both ore and grain vessels. The iron industry often had close ties with coal producing areas, and ore fleets commonly carried coal on the upbound leg of the journey. The iron industry as a whole used large amounts of coal for power in the mining process, so large quantities were required at the same ports from which ore was shipped. In other cases, coal was transported by independent vessel owners to minor ports for use in home heating and nonindustrial power. The combination of links to the iron industry as well as links to smaller transportation operations had the cumulative effect of placing the coal trade somewhere in between iron and grain in overall vessel fleet modernization. Improvements in iron fleets generally resulted in improving the movement of coal, but not always.

The resulting distribution of coal-related vessels can be viewed as a by-product of a vessel fleet that is only partially susceptible to the randomizing effects of storms. Iron-related coal

vessels would theoretically withstand storms better than independent vessels. It could be suggested that more clustered coal vessels (i.e., between Marquette and Sault Ste. Marie) should be those having iron industry links, while vessels in a more random pattern should be independently owned or at least noniron-related vessels. Unfortunately, available data is insufficient to test this proposition at the present time.

Other information relating to this question results from the test of hypothesis 2, which found that vessels for the period 1880-1904 were spatially patterned in a nonrandom distribution, while vessels for the years 1855-1879 and 1905-1929 were randomly distributed. If capital intensity and spatial patterning are closely related as suggested in this model, then it is possible that chronologically, the periods of largest capital inputs will be the periods of most significant distributional agglomeration. The extremely small sample sizes that result when each of the three industries are subdivided into three chronological periods may have an effect on the Poisson tests for distributions. As should be recalled from hypothesis 2, none of the three industries demonstrated nonrandom patterning for any of the periods under consideration. Although not significant at the .05 level, the iron industry had consistently higher D values, indicating more patterning than either grain or coal. When all commodities are combined, the sample size is much larger and the results more reliable. With this combined sample, the three chronological periods indicate some degree of patterning with the middle period 1880-1904 being significantly nonrandom beyond the .005 level of confidence. This period is interesting since it corresponds with the time of highest

capital improvements of the bulk carrier fleets. In 1882, the Onoko was produced as the first large iron bulk carrier on the lakes (Barry 1974). Between that time and 1905, the shipping industry witnessed an unprecedented period of expansion and by the beginning of the twentieth century, the 600-foot carrier had become standard. As discussed in chapter 3, the economic consolidation of iron companies after the 1893 depression spurred this period of capital improvement of fleets. The iron industry led this expansion period and innovations began to filter slowly into other industries. If capital investment is linked with vessel patterning, it would then be expected that vessels for the period 1880-1904 would be more patterned than for either of the previous or later periods.

The scenario thus presented as an explanation for differential vessel distributions by commodity type can be summarized by the proposition that there is a direct correlation between the capital intensity of an industry and the degree of spatial patterning that will occur. A stronger financial base results in more modern vessels less susceptible to the randomizing effects of weather. A counterpart to this model is that the route of transportation is likewise directly related to this loss process because it also has a bearing on the extent to which storms will affect vessels.

Hypothesis 6 illustrated that of the four major iron routes, only vessels from Marquette exhibited nonrandom patterning. This implies that some routes are more conducive to loss than others. The reason or reasons behind this are not revealed in the hypotheses tested in this study, although the results of Hypotheses 1, 6, and 10 consistently point to clustering of lost vessels in zones 36, 54, 57, 58, and 59.

These five zones encompass the areas of western Keweenaw Point, Marquette, and Whitefish Point. A brief analysis of the 64 vessels found in these five zones reveal the following frequencies of losses for each industry.

Table 78. Frequency of losses by industry in five zones

<u>Commodity</u>	<u>Losses in 5 Zones</u>	<u>% Total Industry Losses</u>	<u>Losses in Zones Due to Storms</u>
Iron	41	59	16-39
Grain	12	38	9-75
Coal	11	33	10-91

This table illustrates that approximately 45 percent of all Lake Superior shipwrecks occurred in these five zones. When subdivided by commodity affiliation, it can be seen that 59 percent of all iron vessel losses occurred in these zones compared to 38 percent for grain and 33 percent for coal. The extremely high percentage of losses for iron is further illustration of the highly patterned nature of iron-related wrecks as opposed to either grain or coal. Of special interest is the number of losses due to storms for vessels in these zones. Whereas total iron losses were highest in these zones, the percentage of vessels lost by storms was the lowest at 39 percent. The 75 percent for grain and 91 percent for coal indicate a significantly higher proportion of losses in these same areas. As previously mentioned, this points toward the lower rate of loss due to storms within the iron industry. This lower storm loss rate, along with the clustering effect noted in these five areas, also supports the proposition that patterning would be more nonrandom for iron because of the relative lack of pattern-randomizing storms. Since a lower percentage of iron vessels were lost because of storms in these five zones, the patterning of iron

vessels will likewise be more consistent with the routes of transportation for that industry.

The iron industry focused on ore shipment from four major ports: Duluth, Two Harbors, Ashland, and Marquette. The transportation routes for ore shipment are such that the Two Harbors, Ashland, and Duluth routes intersect off shore of Eagle River on the Keweenaw Peninsula. Before this intersection, the majority of routes are across open water except for the western Apostle Island groupings. After the intersection of traffic has taken place, all vessels from these three ports make several major course changes after rounding the tip of the Peninsula in order to make the southern course for the Sault. One other course change is made off Crisp Point on Whitefish Point before directing vessels to locks and the St. Mary's River. The Marquette route is the only Lake Superior route that follows the southern coastline in close proximity to shore for the entire length of the route. After a relatively minor course change at Au Sable, no other changes are made until Crisp Point when all traffic on Lake Superior merges.

Zones 36, 57, 58, and 59 have several common features that are unique to these areas alone and that may play an important role in understanding the clustering of wrecks in these zones. First, both the Keweenaw and Whitefish areas represent points where several routes intersect and where traffic becomes more congested. In good weather, this would present only minor navigational problems, but could prove hazardous in conditions of poor visibility. Similarly, both areas require major course changes that compound navigation problems in less than perfect weather. The accompanying narrowing of navigation, especially off Whitefish Point, also may play an important factor in

vessel loss. Mansfield notes that "the principal danger to navigation on the lakes is lack of sea room, which leads vessels to run for shelter in a storm and to seek entrance into artificial harbors, which they are liable to miss and to strike upon the piers at the entrance to them" (1899:378). Finally, both areas lie along windward coastlines that take the full brunt of western storms. Being close to land at these two points also means that the likelihood of fog is greatly increased over more open water routes.

Although fog was a variable not directly considered in this study, it was an element mentioned by Wolff (1979) in numerous case studies of individual vessel losses. A reconsideration of this variable has shown that 16 vessel losses occurring between 1855-1930 were influenced to some degree by fog. Of these cases, 81 percent occurred in the five zones under consideration, and all were associated with iron industry vessels. According to the data provided in Appendix B, 44 percent of all collisions on Lake Superior took place within these same five areas. Therefore, fog appears to be an element that affects the iron industry much more than the grain or coal industries.

A probable explanation for the high instances of fog-related losses in the iron industry is that the routes of ore transportation are for the most part closer to land than those of either grain or coal. The Marquette-Sault Ste. Marie route is particularly susceptible because the majority of it is within fog range. In contrast, the Two Harbors, Ashland, Duluth, and Port Arthur routes are close to land only at restricted areas such as the Keweenaw and Whitefish Points. The clustering of wrecks in zones 36, 54, 57, 58, and 59 and the patterning of vessels from Marquette are probably the result of a combination of factors.

Besides being in a high probability fog zone, the Marquette route is also the only route where loss by grounding can occur in close proximity to the actual route being traveled. As hypothesis 10 illustrated, these same zones exhibit a highly clustered pattern of vessels in this loss type. This is as would be expected if narrowed navigation, fog, and course changes played significant roles in vessel loss. Therefore, the clustering of vessels in these zones and along the Marquette route can best be explained by the combination of specific geographic and climatic variables with cultural variables such as navigation routes. The general pattern that emerges is that vessel loss is highest along 1) points of course changes; 2) narrowed navigation; 3) traffic intersections; 4) close proximity to land where fog, collision, and groundings can be major factors; and 5) windward exposed coastlines.

The pattern of vessel loss presented here is specifically applicable to Lake Superior, but the question remains as to its predictive value in other areas. The information generated by this study is useful in determining only general patterning of loss, not specific geographic areas where loss takes place. In other areas, Lake Michigan for example, the pattern of loss could be quite different because of geography, navigation, weather, and other variables that are different from the Lake Superior region. On the other hand, the principal agents in determining loss patterning may be the same for all the Great Lakes. If so, then given the variables of deposition that have been derived, it could be possible to outline likely areas of loss for other waterbodies. This is a proposition that can be tested during the course of future historical and archaeological inquiry. When the concept of

capital intensity and patterning is introduced into this system, very specific hypotheses can be tested for other regions and a theoretical foundation for shipwreck studies can be laid down. Using the information provided in chapter 3 on such characteristics as the chronological sequence of ore types (hard, soft, Bessemer, graded, etc.) and grain varieties (hard, soft, white, red), extremely detailed hypotheses could be generated for testing with a data base more extensive than for Lake Superior. With only 146 vessels available in this study, more specific hypotheses could not be sufficiently prepared and analyzed. However, with a sample size of 300 vessels, models could be developed that could be tested with historical and archaeological data. Additionally, the information from chapter 3 can be used to date vessels of unknown origin using cargo samples if archaeological investigations on shipwrecks do occur. Therefore, the model of deposition presented in this text is to be regarded as a general foundation upon which more complex distributional models can be built.

Type B: Archaeological Transforms

Hypotheses 16-21 concern the effects of salvage on Lake Superior shipwrecks. After shipwrecks are deposited in situ on the bottomlands, a number of factors influence the degree to which they are preserved and/or decomposed. A number of these factors such as ice damage, decomposition due to the limnological conditions, etc. are currently unknown and can only be investigated through direct observation of the archaeological record. But other variables, such as salvage, are historically documented to some extent and can be investigated within the scope of this study. When viewed as an archaeological transform, salvage is an extremely important variable because it directly affects

the extent of the archaeological record.

Since this study focuses upon the question of spatial representativeness of Lake Superior shipwrecks, the element of salvage must also be reviewed for its effect upon the distribution of lost vessels. The major question here is to what extent salvage alters the spatial arrangement of shipwrecks from initial pattern of deposition. Hypothesis 19 is particularly relevant in answering this question because it has shown that collectively, salvage is a patterned nonrandom phenomena. Four zones in particular had heavy clusters of salvaged vessels--zones 44, 54, 36, 59. The first two zones are port areas for Duluth and Marquette and represent the two busiest ports on Lake Superior. Apparently, salvage is undertaken at higher rates within close proximity to major ports. This is not unusual since distressed vessels can be reached soon after loss, which aids the salvage procedure. Likewise, the relative closeness of other vessels such as tugs allows for towing of unnavigable wrecks and the freeing of vessels from grounded locations.

The two other locations of highest salvage frequency were the Keweenaw Peninsula between Eagle River and Copper Harbor and the section encompassing Whitefish Point and the waterway to the Sault. These areas (zones 36 and 59) are also in close proximity to major ports and salvage facilities at Houghton and Sault Ste. Marie, and both areas are accessed within 25 miles or less of the respective ports and are therefore quite close in relation to the vast area of Lake Superior. The other major ports of Two Harbors, Ashland, and Port Arthur also have several instances of salvage close to harbor facilities, although no significant clusters of totally lost or salvaged vessels occur at these areas.

Another factor that may influence the spatial distribution of salvaged vessels is the type of loss that brought about the initial wreck. Hypothesis 20 demonstrated an association between loss type and extent of salvage, with groundings being salvaged more frequently than other loss types and founderings less frequently. Remembering that hypothesis 10 illustrated that groundings cluster in zones 36, 54, 56, and 58, it is not surprising that salvage of grounded vessels is also more frequent in these areas. That vessels in these zones grounded at a higher rate than in other areas may also be an explanation for why salvage was also conducted at higher rates in zones 36 and 54. Although groundings are of varying degrees of severity, this type of loss is generally more conducive to salvage because of shallower water depths. Many groundings are minor matters for salvage and can be conducted in a few days by simply releasing the vessel from a reef or shore and patching damaged hulls. The tendency for founderings to be salvaged at a lower rate is because most occur in the open, deep waters of Lake Superior. Until the middle of the twentieth century, salvage of deep-water wrecks was a rarity and would not have been attempted on the lake for the time period dealt with in this study. From Appendix B, it can be seen that only four vessels lost before 1885 were ever salvaged. In two of these cases, Queen of the Lake and Bermuda, salvage was not undertaken until many years after the loss had occurred (Wolff 1980: 54-55). Salvage on Lake Superior was therefore not a factor before the 1880s, so spatial patterns for the early period of the lake would remain unaffected by this variable.

The variable of vessel type was shown in hypothesis 16 to be another factor that was differentially affected by salvage. While some

vessel types such as schooners and schooner-barges were salvaged at low rates, other types such as steel steamers were salvaged considerably more often. The results of this hypothesis illustrate that there is a strong tendency for more valuable vessels to be salvaged at a higher rate. For example, steel steamers are larger, more costly to produce, and have a higher scrap value for engines, metal and so forth. Their larger capacity in contrast to other vessel types also means that more cargo will be carried on a given voyage with a higher total value. Schooners and schooner-barges were less expensive to produce, had little "scrap" value since they were built of wood, and carried smaller amounts of cargo in a single trip. They also had shorter life expectancies and given the fact that most schooner-barges were conversions of older schooners, the life span of these sailing vessels was probably reached while in service. As hypothesis 12 has shown, schooner-barges were particularly susceptible to loss by foundering, which may have been accentuated by vessel age. Together, these variables make it expectable that some vessel types were salvaged at higher or lower rates than others. An analogy would be that most people today do not expend large sums of money on the repair of ten-year-old automobiles that have been in accidents. It is not cost efficient to save a vehicle that has already reached its life expectancy, just as it is not feasible to salvage a vessel of low value. In terms of vessel type, it is important that the vessels that form the shipwreck archaeological record are not reflections of the same types of vessels that were originally lost. Taken collectively, the salvage variable is a major influence on the formation of the archaeological record. The spatial distributions of vessels is altered by the patterns of salvage since it occurs more

often near coastline areas and close to major ports. Also, some vessel types and loss types are salvaged more often than others, which influences the relative frequencies of vessels in the archaeological context. As a Type B transform, the element of salvage is a significant factor in the patterning of Lake Superior vessels.

Conclusion

While the primary goal of this study was the investigation of spatial patterning and shipwreck formation, a broader underlying goal was the demonstration of the applicability of shipwreck data to nonparticularistic research. The current state of shipwreck studies nationwide is that they are primarily oriented toward history and architecture and not toward more holistic issues. Although this is a slight improvement on the antiquated philosophy of the past, the historical approach still does not address shipwrecks as reflections of a cultural phenomena. In other regions of the country, the focus is on chronologically earlier vessels about which little or nothing is known in regard to architecture, artifacts, or historical movements of people and supplies. In these areas, archaeology as history contributes to the body of historic knowledge in a substantial manner-albeit limited in social interpretation. Research can therefore be justified to some extent because of the contribution to such disciplines as marine history and architecture. In the Great Lakes region, the situation is very different from coastal areas. On Lake Superior, for example, vessels are primarily from the post-1855 period, which is documented more extensively than other regions. For many vessels, historians know the architecture through written documents such as blueprints. Likewise,

the artifacts found on vessels, especially from the twentieth century, are not particularly valuable or unique as objects of interest. For these reasons, the shipwrecks of the Great Lakes, particularly Lake Superior, are of little value in the strict historic sense because they do not contribute knowledge about specific people, events, or objects of the past. This in part is a reason for the lack of research on Great Lakes shipwrecks by historically-trained underwater archaeologists.

While Lake Superior shipwrecks are of limited interest to traditional historians, they have great potential for anthropologists as reflections of culture process. The major finding of this study is actually that shipwrecks can be used as a data base for solving broader social questions about the past. This research has analyzed historical case studies and applied them to propositions that involve the past as an interrelated system. A systems approach recognizes that the past is more than just the "big events" that historians portray.

In addition, this study has addressed several questions that are immediately relevant to the study of Great Lakes shipwrecks from an archaeological perspective. As a region, Lake Superior is extremely well-researched, the documented wreck sites within its boundaries constitute a major portion of the vessel population lost during the period 1855-1930. Before 1855, settlement and development of the Lake Superior region was extremely sparse and limited. The effect of the Industrial Revolution on the area created an aspect of culture change that is unique in comparison to other portions of the country. Lake Superior represents a tightly confined geographic area that was developed solely in response to industrial expansion and the need for raw materials. The spatial configuration of towns, industrial camps

(iron, charcoal, lumber, etc.), and shipwrecks was a result of industrialization that no other part of the country experienced. Through the spatial analysis of this region, industrialization can be given significance as a cultural phenomenon, rather than as the technological phenomenon recognized by economic historians. Shipwrecks as an industrial phenomenon therefore have great potential for providing information on the process of the culture change that swept the Great Lakes region.

Analysis of this shipwreck population suggests that there is a direct correlation between the capital intensity of an industry (i.e., ability to make capital improvements) and the degree of spatial patterning that results in wreck deposition. This is a hypothesis that can be tested for the other Great Lakes and may have relevance to many other shipwreck distributions. It is also a proposition that may have some use in dealing with industrial archaeological sites on land because theoretically, technological innovations are diffused geographically across lines of capital investment. For land sites, the actual mechanisms patterning would be very different because the randomizing effects of storms would not apply and specific models of diffusion and deposition would necessarily have to be generated in order to apply to these sites. However, this proposition can be tested and may shed some light on the mechanisms of change and spatial patterning sought by both anthropologists and geographers.

As reflections of past cultural systems, shipwrecks can provide a great deal of information useful to archaeological research. But this study has also demonstrated that in many ways, shipwrecks are not representative of every aspect of economic development and change that

has taken place. There are many questions that shipwreck data cannot answer in regard to the past. Shipwrecks are a culturally structured phenomena as are all archaeological sites, but this alone does not assure that the archaeological record is representative in every way of the culture from which it originated. The spatial analysis of Lake Superior shipwrecks resulted in the rejection of many hypotheses from the expected patterns. Vessels were differentially distributed by industry, port of origin, vessel type, and loss type. Therefore, the shipwrecks that now comprise the archaeological record are patterned in specific ways that do not directly reflect all aspects of culture change and development. Future research must consider these limitations and ask questions that are testable, given the condition of the archaeological record.

By expanding the transform concept into two separate processes, this study has introduced an amended version of Schiffer's (1972) model of the formative process of the archaeological record. The processes of deposition and decomposition are useful to the understanding of shipwreck distributions. These same concepts have utility for all archaeological phenomena since the material culture initially deposited in situ undergoes numerous changes before the archaeological investigation. This transformation process has a great deal of relevance for this study because spatial patterning reflected the cultural developments that affected the Lake Superior region.

The real importance of patterning lies in an understanding of the interrelatedness of cultural and environmental processes that created the present distribution of shipwrecks. The interactions of trade routes, industries, developmental chronology, weather, land forms,

and a whole array of other cultural and natural factors have produced the spatially patterned archaeological record that archaeologists must now study.

The implication of this study to future shipwreck research is that a regional view must be maintained in order to fully understand the processes of change and development that effected the entire area. If only one small geographic area within the region had been selected for study, an extremely biased set of results would have been obtained. Since clustering of wreck sites is a patterning phenomenon influenced by particular variables, the study of such a single cluster would likewise be representative of atypical cultural and environmental conditions. For example, because iron industry vessels tended to cluster while coal and grain vessels dispersed, the major concentrations of wrecks tend to be heavily biased toward iron. Additionally, because the iron industry lost particular vessel types at higher rates than others and by particular types of loss, the concentrations of vessels would also be nonrepresentative of the types of vessels that actually sailed the region. Extreme caution must be maintained if individual wreck concentrations are evaluated and interpreted outside of a regional format. If a representative cross-section of industries and types is desired, then spatially diverse individual wreck sites must be sought. In a similar vein, if protection of a cross-section of Great Lakes vessels is desired, then the protection of only major wreck concentrations will not fulfill this desire.

Hopefully, this study has provided some useful explanations and insights into the phenomena of Great Lakes shipwrecks. As with any research, many questions are raised--and this study is no exception.

The archaeological resource that is least known and understood is that of the shipwreck. The estimated 6,000 wrecks that have occurred in the Great Lakes encapsulate the culture of the region, if not the nation. This study has focused on 146 vessels--a small number in comparison to what may lie beneath the waters. The old adage "out of sight, out of mind" must not apply to this phenomenon. The propositions posed and discussed in this study are only the beginning steps toward creating a basis for scientific research and analysis. If not, then this study has not fulfilled its goal of demonstrating the relevance and importance of shipwreck study for the whole of archaeological understanding.

APPENDIX A

APPENDIX A

Table 1. Opening and closing of navigation

Year	Opened	Closed	Year	Opened	Closed
1855	June 13	Nov. 23	1893	May 5	Dec. 7
1856	May 4	Nov. 28	1894	April 17	Dec. 9
1857	May 9	Nov. 30	1895	April 25	Dec. 11
1858	April 18	Nov. 20	1896	April 16	Dec. 8
1859	May 3	Nov. 28	1897	April 22	Dec. 12
1860	May 11	Nov. 26	1898	April 13	Dec. 14
1861	May 3	Nov. 14	1899	May 2	Dec. 18
1862	April 27	Nov. 27	1900	April 19	Dec. 12
1863	April 28	Nov. 28	1901	April 26	Dec. 11
1864	May 2	Dec. 24	1902	April 2	Dec. 20
1865	May 1	Dec. 3	1903	April 9	Dec. 15
1866	May 5	Dec. 3	1904	May 5	Dec. 13
1867	May 4	Dec. 3	1905	April 14	Dec. 16
1868	May 2	Dec. 3	1906	April 13	Dec. 17
1869	May 4	Dec. 29	1907	April 23	Dec. 11
1870	April 29	Dec. 1	1908	April 27	Dec. 13
1871	May 8	Nov. 29	1909	April 26	Dec. 16
1872	May 11	Nov. 26	1910	April 12	Dec. 15
1873	May 5	Nov. 18	1911	April 22	Dec. 16
1874	May 12	Dec. 2	1912	April 24	Dec. 19
1875	May 12	Dec. 2	1913	April 19	Dec. 18
1876	May 3	Nov. 26	1914	April 23	Dec. 17
1877	May 2	Nov. 30	1915	April 18	Dec. 20
1878	May 8	Dec. 3	1916	April 20	Dec. 19
1879	May 2	Dec. 3	1917	April 24	Dec. 17
1880	April 28	Nov. 15	1918	April 24	Dec. 14
1881	May 7	Dec. 5	1919	April 10	Dec. 16
1882	April 21	Dec. 3	1920	April 19	Dec. 26
1883	May 2	Dec. 11	1921	April 7	Dec. 24
1884	April 23	Dec. 10	1922	April 17	Dec. 24
1885	May 6	Dec. 2	1923	May 4	Dec. 26
1886	April 25	Dec. 24	1924	April 19	Dec. 19
1887	May 1	Dec. 20	1925	April 13	Dec. 16
1888	May 7	Dec. 4	1926	April 29	Dec. 14
1889	April 15	Dec. 4	1927	April 13	Dec. 14
1890	April 20	Dec. 3	1928	May 3	Dec. 14
1891	April 27	Dec. 8	1929	April 14	Dec. 14
1892	April 15	Dec. 7	1930	April 22	Dec. 15

Sources: Mansfield 1899:508; Hickok 1938:321.

Table 2. Upper Peninsula forges and furnaces

<u>Name</u>	<u>Dates of Operation</u>	<u>Production</u>	<u>Port of Shipment</u>
Carp River Forge	1848-1857		MAR
Marquette Iron Co.	1850-1853		MAR
Forest Iron Co.	1855-1862		MAR
Collins Forge	1855-1858	41,997	MAR
Collins Experimental Furnace	1858-1858		MAR
Pioneer No. 1 Stack	1858-1892		MAR
Collins Blast Furnace	1858-1873		MAR
Northern Furnace	1860-1910	30,059	MAR
Pioneer No. 2 Stack	1859-1893	637,299	MAR
Bancroft Furnace	1861-1876	55,608	MAR
Morgan Furnace	1863-1879	57,573	MAR
Greenwood Furnace	1865-1875	40,202	MAR
Michigan Furnace	1867-1875	41,531	MAR
Schoolcraft Furnace (Munising)	1868-1877	28,312	MUN
Jackson No. 1 Stack	1867-1890		N/A
Champion Furnace	1867-1874	31,048	MAR
Deer Lake No. 1 Stack	1868-1891		MAR
Jackson No. 2 Stack	1870-1890	229,228	N/A
Bay Furnace No. 1 Stack	1870-1877		Christmas
Marquette & Pacific	1871-1882	41,857	MAR
Peat Furnace (Excelsior)	1872-1897		MAR
Grace Furnace	1872-1874	11,346	MAR
Bay Furnace No. 2 Stack	1872-1877	50,706	Christmas
Escanaba Furnace (Cascade)	1873-1874	8,650	N/A
Menominee Furnace	1873-1883	59,553	N/A
Carp River Furnace	1874-1907	83,500	MAR
Deer Lake No. 2 Stack	1874-1891	93,579	MAR
Cliffs Furnace	1874-1877	8,209	MAR
Martel Furnace	1881-1903	58,349	N/A
Vulcan Furnace	1883-1945	73,829	N/A
Iron River Furnace (Gogebic)	1886-1888	3,700	N/A
Weston Furnace	1891-1922		N/A
Gladstone Furnace	1896-1922		N/A

Production figures for two furnaces

Source: LaFayette 1977:49.

MUN - Munising

MAR - Marquette

N/A - Other than Lake Superior port

Table 3. Iron ore shipments by range

Year	Marquette	Menominee	Vermillion	Gogebic	Mesaba
1854	3,000				
1855	1,449				
1856	36,343				
1857	35,646				
1858	65,878				
1859	68,832				
1860	124,401				
1861	49,909				
1862	124,169				
1863	203,055				
1864	243,127				
1865	236,208				
1866	278,796				
1867	473,567				
1868	491,449				
1869	617,444				
1870	830,940				
1871	779,607				
1872	900,901				
1873	1,162,458				
1874	919,557				
1875	891,257				
1876	992,764				
1877	1,010,494	4,593			
1878	1,033,082	78,028			
1879	1,130,019	245,672			
1880	1,348,010	524,735			
1881	1,597,834	727,171			
1882	1,829,394	1,136,018			
1883	1,305,425	1,047,415			
1884	1,548,034	895,634	62,124	1,022	
1885	1,480,422	690,435	225,484	119,860	
1886	1,627,380	880,006	304,396	753,362	
1887	1,851,414	1,193,343	394,252	1,322,878	
1888	1,923,737	1,191,101	511,953	1,437,096	
1889	2,642,813	1,796,754	884,682	2,008,394	
1890	2,993,664	2,282,237	880,014	2,847,810	
1891	2,512,242	1,824,619	894,618	1,839,574	
1892	2,666,856	2,261,499	1,167,650	2,971,991	4,425
1893	1,835,893	1,466,197	820,621	1,329,385	613,620
1894	2,049,107	1,137,949	948,513	1,809,468	1,793,052
1895	2,097,838	1,923,798	1,077,838	2,547,976	2,781,587
1896	2,604,221	1,560,467	1,088,090	1,799,971	2,882,079
1897	2,715,035	1,937,012	1,278,481	2,258,236	4,280,873
1898	3,119,000	2,522,000	1,265,000	2,498,000	4,614,000
1899	3,738,000	3,301,000	1,772,000	2,799,000	6,614,000
1900	3,479,000	3,261,000	1,656,000	2,877,000	7,810,000
1901	3,247,000	3,619,000	1,786,000	2,938,000	9,005,000

Table 3. Iron ore shipments by range continued

Year	Marquette	Menominee	Vermillion	Gogebic	Mesaba
1902	3,865,000	4,613,000	2,084,000	3,659,000	13,331,000
1903	3,040,000	3,750,000	1,677,000	2,939,000	12,894,000
1904	2,852,000	3,075,000	1,283,000	2,399,000	12,157,000
1905	4,236,000	4,495,000	1,677,000	3,706,000	20,159,000
1906	4,057,000	5,110,000	1,793,000	3,642,000	23,821,000
1907	4,388,000	4,965,000	1,685,000	3,633,000	27,492,000
1908	2,414,000	2,679,000	842,000	2,700,000	17,258,000
1909	4,253,000	4,875,000	1,109,000	4,088,000	28,168,000
1910	4,393,000	4,238,000	1,203,000	4,316,000	29,200,000
1911	2,836,000	3,911,000	1,089,000	2,603,000	22,099,000
1912	4,203,000	4,711,000	1,845,000	5,006,000	32,045,000
1913	3,968,000	4,967,000	1,567,000	4,532,000	34,040,000
1914	2,494,000	3,222,000	1,017,000	3,569,000	21,468,000
1915	4,106,000	4,983,000	1,734,000	5,478,000	29,757,000
1916	5,410,000	6,365,000	1,947,000	8,490,000	42,526,000
1917	4,874,000	6,046,000	1,531,000	7,980,000	41,441,000
1918	4,354,000	6,379,000	1,193,000	7,937,000	40,399,000
1919	2,992,000	4,447,000	929,000	6,230,000	32,004,000
1920	4,608,000	6,569,000	1,007,000	8,763,000	37,150,000
1921	1,117,000	1,584,000	869,000	2,337,000	16,360,000
1922	2,818,000	4,079,000	1,212,000	6,221,000	28,064,000
1923	3,892,000	4,855,000	1,279,000	6,580,000	41,806,000
1924	3,175,000	3,837,000	978,000	5,160,000	29,142,000
1925	4,198,000	5,270,000	1,438,000	7,068,000	35,890,000
1926	4,435,000	5,946,000	1,586,000	7,537,000	38,251,000
1927	4,148,000	5,213,000	1,548,000	6,386,000	32,976,000
1928	4,299,000	4,842,000	1,671,000	6,540,000	35,399,000
1929	5,410,000	5,645,000	1,874,000	7,624,000	43,008,000
1930	3,634,000	3,609,000	1,885,000	5,064,000	31,067,000

Sources: Mansfield 1899:566; Hickok 1938:308

Table 4. Grain and flour shipments—Lake Superior 1870-1911

Year	Grain Shipment	Flour Shipment
1870	10.0	3.7
1871	50.0	2.9
1872	29.5	15.0
1873	72.3	19.0
1874	37.8	19.8
1875	43.4	34.1
1876	70.6	34.6
1877	50.1	39.1
1878	63.6	37.8
1879	104.7	49.6
1880	134.5	57.6
1881	114.0	66.5
1882	125.1	37.8
1883	195.8	75.6
1884	374.1	137.3
1885	470.1	158.4
1886	589.9	193.5
1887	714.6	172.9
1888	614.5	240.9
1889	546.7	245.1
1890	543.7	356.2
1891	1193.4	415.8
1892	1276.5	596.0
1893	1371.8	816.3
1894	1089.3	986.2
1895	1619.8	979.2
1896	2666.2	977.1
1897	2265.4	981.3
1898	2600.4	855.6
1899	2591.1	782.5
1900	899.9	688.0
1901	1090.9	633.3
1902	1193.2	743.7
1903	958.0	564.9
1904	986.0	442.7
1905	1174.1	454.1
1906	1580.5	583.8
1907	1626.2	515.1
1908	1570.3	402.8
1909	2067.0	455.4
1910	1161.7	455.0
1911	1116.0	459.1

Shipments given in thousand tons.

Table 5. Coal Shipment--Lake Superior 1855-1919

Year	Amount	Year	Amount
1855	1,414	1888	2,105,041
1856	3,968	1889	1,629,197
1857	5,278	1890	2,176,925
1858	4,118	1891	2,507,532
1859	8,884	1892	2,904,266
1860		1893	3,008,120
1861	11,507	1894	2,797,184
1862	11,346	1895	2,574,362
1863	7,805	1896	3,023,340
1864	11,282	1897	3,029,172
1865		1898	3,776,450
1866	19,915	1899	3,940,900
1867	22,927	1900	2,896,100
1868	25,814	1901	4,240,000
1869	27,850	1902	4,300,800
1870	15,952	1903	6,022,400
1871	46,798	1904	5,935,400
1872	80,815	1905	5,643,200
1873	96,780	1906	7,637,500
1874	61,123	1907	9,683,400
1875	101,260	1908	8,227,900
1876	124,734	1909	8,121,200
1877	91,575	1910	13,513,727
1878	91,856	1911	15,332,876
1879	110,704	1912	14,931,594
1880	170,501	1913	18,662,938
1881	295,647	1914	14,487,221
1882	430,184	1915	13,357,058
1883	714,444	1916	16,123,119
1884	706,379	1917	18,298,853
1885	894,991	1918	17,981,610
1886	1,009,999	1919	13,874,951
1887	1,352,987		

Sources: Mansfield 1899:194; MacElwee 1921:242; Williamson 1977:234-235

APPENDIX B

VESSEL DATA

IRON ORE - TOTAL LOSSES

Vessel Name	Vessel Type	Date of Loss	Condition of Loss	Port of Origin	Location lost (Poisson Zone)	Storms Present
Indiana	propeller	June 1858	foundering	Marquette	58	
Oriole	schooner	Aug. 9, 1862	collision	Marquette	56	
Oneida Chief	schooner	May 1868	grounding	Marquette	56	
Nucleus	schooner	Sept. 1869	foundering	Marquette		
W W Arnold	schooner	Nov. 5, 1869	grounding	Marquette	58	X
Desoto	schooner	Dec. 4, 1869	grounding	Marquette	54	X
Jupiter	schooner/barge	Nov. 27, 1872	grounding	Marquette	58	X
Saturn	schooner/barge	Nov. 27, 1872	grounding	Marquette	58	X
Cambridge	schooner	Aug. 1873	grounding	Marquette	54	X
Union	propeller	Sept. 25, 1873	grounding	Marquette	56	X
Comet	propeller	Aug. 26, 1875	collision	Munising	59	
Shenango	schooner/barge	Nov. 20, 1875	grounding	Marquette	55	X
Mary Jarecki	steam barge	July 4, 1883	grounding	Marquette	56	
J M Osborne	wood steam barge	July 27, 1884	collision	Marquette	59	

IRON ORE - TOTAL LOSSES (CONTINUED)

Vessel Name	Vessel Type	Date of Loss	Condition of Loss	Port of Origin	Location lost (Poisson Zone)	Storms Present
F W Wheeler	schooner/barge	Sept. 29, 1885	foundering	Two Harbors	57	
Eureka	schooner/barge	Oct. 20, 1886	foundering	Marquette	58	X
Lucerne	schooner/barge	Nov. 17, 1886	foundering	Ashland, WI	47	X
Niagara	schooner/barge	Sept. 7, 1887	foundering	Ashland, WI	58	X
Smith Moore	wood steam barge	June 13, 1889	collision	unknown		
Bessemer	wood steam barge	Oct. 5, 1889	foundering	Ashland, WI	35	X
Schuykill	schooner/barge	Oct. 5, 1889	foundering	Ashland, WI	35	X
Comrode	schooner/barge	Oct. 12, 1890	foundering	Ashland, WI	11	X
Vienna	wood steamer	Sept. 16, 1892	collision	Marquette	59	
James Picklands	wood steamer	Sept. 22, 1894	grounding	Duluth	36	
Joseph Paige	schooner/barge	Nov. 30, 1897	grounding	Marquette	58	X
	whaleback barge	Dec. 13, 1899	grounding	unknown	6	X
R Hollaran	schooner/barge	May 2, 1900	foundering	Two Harbors	38	
Sagamore	whaleback barge	June 29, 1901	collision	unknown	59	

IRON ORE - TOTAL LOSSES (CONTINUED)

Vessel Name	Vessel Type	Date of Loss	Condition of Loss	Port of Origin	Location lost (Poisson Zone)	Storms Present
Michigan	schooner/barge	Oct. 2, 1901	foundering	unknown	58	X
M M Drake	wood steamer	Oct. 2, 1901	collision	unknown	58	X
Thomas Wilson	whaleback steamer	June 7, 1902	collision	Duluth	44	
	whaleback barge	Oct. 1902	collision	unknown	41	X
Robert Wallace	wood steamer	Nov. 17, 1902	foundering	Duluth	46	
Moonlight	schooner/barge	Sept. 19, 1903	foundering	Ashland, WI	48	X
A A Parker	wood steamer	Sept. 19, 1903	foundering	Superior	56	X
Marquette	wood steamer	Oct. 3, 1903	foundering	Ashland, WI	47	X
William F. Sanber	wood steamer	Oct. 26, 1903	foundering	Ashland, WI	58	X
Sitka	wood steamer	Sept. 10, 1904	grounding	Marquette	56	
Sevona	steel steamer	Sept. 2, 1905	grounding	Superior	47	X
Pretoria	schooner/barge	Sept. 2, 1905	foundering	Duluth	32	X
Olive Jesnette	schooner/barge	Sept. 2, 1905	foundering	Duluth		X
Iosco	wood steamer	Sept. 2, 1905	unknown	Duluth		



IRON ORE - TOTAL LOSSES (CONTINUED)

Vessel Name	Vessel Type	Date of Loss	Condition of Loss	Port of Origin	Location lost (Poisson Zone)	Storms Present
Batchawanna	wood steamer	June 26, 1907	fire	Fort William	59	
Cyprus	steel steamer	Oct. 11, 1907	foundering	Superior	57	
Neshato	wood steamer	Sept. 27, 1908	grounding	Superior	58	
John B. Cowle	steel steamer	July 12, 1909	collision	unknown	59	
Culligan	wood steamer	Sept. 27, 1912	foundering	Marquette		
Henry B. Smith	steel steamer	Nov. 9, 1913	foundering	Marquette	54	X
S R Kirby	iron/wood steamer	May 8, 1916	foundering	Ashland, WI	36	X
Superior City	steel steamer	Aug. 20, 1920	collision	Two Harbors	59	

IRON ORE - SALVAGED

Vessel Name	Vessel Type	Date of Loss	Condition of Loss	Port of Origin	Location lost (Poisson Zone)	Storms Present
Queen of the Lakes	propeller	June 12, 1869	fire	Marquette	54	
Bermuda	schooner	Oct. 1870	grounding	Marquette	55	X
E G Hale	propeller	Aug. 30, 1886	grounding	unknown	59	
Fagette Brown	schooner/barge	Aug. 30, 1886	grounding	unknown	59	
Republic	schooner	Nov. 26, 1886	grounding	Marquette	62	X
Monterey	schooner	June 19, 1889	grounding	unknown	59	
Magnetic	schooner/barge	Apr. 29, 1890	collision	Marquette	65	
Melris S. Bacon	schooner/barge	Sept. 25, 1905	fire	Ashland, WI	47	
Frank Rockefeller	whaleback steamer	Nov. 2, 1905	grounding	Duluth	19	X
Maida	steel barge	Nov. 2, 1905	grounding	Duluth	19	
William E. Corey	steel steamer	Nov. 28, 1905	grounding	unknown	48	X
Uranus	steel steamer	May 25, 1906	grounding	unknown	36	
Daniel B. Meachan	steel steamer	Oct. 24, 1908	grounding	Superior	36	
Pathfinder	whaleback steamer	Aug. 9, 1909	grounding	unknown	36	

IRON ORE - SALVAGED (CONTINUED)

Vessel Name	Vessel Type	Date of Loss	Condition of Loss	Port of Origin	Location lost (Poisson Zone)	Storms Present
Sagamore	steel barge	Aug. 9, 1909	grounding	Eagle River	36	
John O. Trevor	whaleback steamer	Oct. 11, 1909	grounding	unknown	19	X
Bransford	steel steamer	Nov. 15, 1909	grounding	Duluth	20	X
Zenith City	steel steamer	July 26, 1910	grounding	Marquette	56	
William C. Moreland	steel steamer	Oct. 18, 1910	grounding	Superior	36	
L C Waldo	steel steamer	Aug. 8, 1913	grounding	Two Harbors	36	X
J T Hatchinson	steel steamer	Nov. 10, 1913	grounding	Duluth	64	X
Fred G. Hartwell	steel steamer	Nov. 10, 1913	grounding	Duluth	64	X
George F. Baker	steel steamer	May 5, 1914	grounding	Ashland, WI	36	
J H Sheadle	steel steamer	Nov. 20, 1921	grounding	Marquette	54	
Hoover and Mason	steel steamer	May 17, 1924	collision	Superior	44	

GRAIN - TOTAL LOSSES

Vessel Name	Vessel Type	Date of Loss	Condition of Loss	Port of Origin	Location lost (Poisson Zone)	Storms Present
Plover	schooner	Oct. 12, 1871	grounding	Duluth	58	X
W O Brown	schooner	Nov. 27, 1872	grounding	Duluth	43	X
Charles C. Griswold	schooner	Nov. 27, 1872	foundering	Duluth	59	X
Geneva	wood steamer	Oct. 23, 1873	foundering	Duluth	41	
Manistee	wood propeller	Nov. 10, 1883	foundering	Duluth		
Morley	wood steamer	Nov. 21, 1884	grounding	Duluth	57	X
Samuel Mather	wood steamer	Nov. 14, 1891	collision	Duluth	59	
J W Comstock	schooner/barge	Sept. 21, 1895	foundering	Duluth	38	X
Missoula	wood steamer	Nov. 2, 1895	foundering	Duluth	59	
Servia	wood steamer	Apr. 27, 1898	fire	Duluth	58	
Colorado	wood steamer	Sept. 19, 1898	grounding	Duluth	36	X
Henry Chisholm	wood steamer	Oct. 17, 1898	grounding	Duluth	19	X
Hudson	steel freighter	Sept. 16, 1901	unknown	Duluth	36	X
Bannackburn	steamer	Nov. 21, 1902	unknown	Port Arthur		X

GRAIN - TOTAL LOSSES (CONTINUED)

Vessel Name	Vessel Type	Date of Loss	Condition of Loss	Port of Origin	Location lost (Poisson Zone)	Storms Present
Manhattan	wood steamer	Oct. 26, 1903	grounding	Duluth	62	X
Ira H. Owen	steamer	Nov. 28, 1905	foundering	Duluth	16	X
Strathmore	wood steamer	Nov. 14, 1906	grounding	Fort William	26	X
Golspie	wood steamer	Nov. 28, 1906	grounding	Fort William	28	X
Monarch	wood steamer	Dec. 6, 1906	grounding	Port Arthur	11	X
Ottawa	steel steamer	Nov. 15, 1909	foundered	Port Arthur	12	X
Orioko .	iron steamer	Sept. 14, 1915	foundering	Duluth	45	
Alfred P. Wright	wood steamer	Nov. 13, 1915	fire	Duluth	32	X
Chester A. Congdon	steel steamer	Nov. 6, 1918	grounding	Ft. William	10	X
John Owen	composite steamer	Nov. 8, 1919	unknown	Duluth		X
Tioga	steamer	Nov. 26, 1919	grounding	Duluth	36	X
Glenlyou	package freighter	Nov. 1, 1924	grounding	Fort William	20	X

GRAIN - SALVAGED

Vessel Name	Vessel Type	Date of Loss	Condition of Loss	Port of Origin	Location lost (Poisson Zone)	Storms Present
Georgian	propeller	June 26, 1884	grounding	Port Arthur	7	
Robert Wallace	wood steamer	Nov. 18, 1886	grounding	Duluth	54	X
David Wallace	barge	Nov. 18, 1886	grounding	Duluth	54	X
Montana	wood steamer	Sept. 26, 1895	foundering	Duluth	35	X
Centurian	steel steamer	Oct. 23, 1895	grounding	Duluth	20	X
Arthur Orr	steel pkg. freighter	Nov. 22, 1898	grounding	Duluth	30	X
Avon	wood steamer	June 30, 1901	fire	Duluth	60	
William Nottingham	steel steamer	Nov. 10, 1913	grounding	unknown	59	X
Ralph Budd	steel steamer	May 15, 1929	grounding	Duluth	36	X

COAL - TOTAL LOSSES

Vessel Name	Vessel Type	Date of Loss	Condition of Loss	Port of Origin	Location lost (Poisson Zone)	Storms Present
John L. Gross	schooner	Nov. 1873	grounding	unknown	36	
Laura Bell	schooner	Sept. 9, 1883	grounding	unknown	54	X
Florida	schooner	Nov. 17, 1886	grounding	unknown	54	X
George Sherman	schooner	Oct. 23, 1887	grounding	unknown	54	X
Atlanta	schooner	May 3, 1891	foundering	Westband	58	X
Frank Perew	schooner	Sept. 29, 1891	foundering	unknown	59	X
George	schooner	Oct. 24, 1893	grounding	unknown	55	X
Antelope	schooner/barge	Oct. 7, 1897	foundering	unknown	48	
Nelson	schooner/barge	May 13, 1899	foundering	unknown	57	X
Pasadern	schooner	Oct. 8, 1906	grounding	unknown	35	X
Elgin	schooner/barge	Oct. 28, 1906	foundering	unknown	17	
Parrama	wood steamer	Nov. 21, 1906	grounding	unknown	49	X
Alex Nimick	wood steamer	Sept. 21, 1907	grounding	unknown	58	X
Lizzie A. Law	schooner/barge	Oct. 22, 1908	grounding	unknown	36	X

COAL - TOTAL LOSSES (CONTINUED)

Vessel Name	Vessel Type	Date of Loss	Condition of Loss	Port of Origin	Location lost (Poisson Zone)	Storms Present
D M Clemson	steel steamer	Dec. 1, 1908	unknown	Loraine	57	
Langhorn	wood steamer	Oct. 23, 1910	fire	unknown		
John Mitchell	steel steamer	July 10, 1911	collision	unknown		
Rappannock	wood steamer	July 25, 1911	grounding	unknown	5	X
James Gayley	steel steamer	Aug. 7, 1912	collision	unknown	13	
Gale Staples	wood steamer	Oct. 1, 1918	grounding	unknown	56	X
Ferinand Schlesinger	wood steamer	May 26, 1919	foundered	unknown	12	
H E Runnels	lumber hooker	Nov. 14, 1919	grounding	unknown	57	X
Maplehurst	steel steamer	Nov. 30, 1922	foundering	unknown	35	X

COAL - SALVAGED

Vessel Name	Vessel Type	Date of Loss	Condition of Loss	Port of Origin	Location lost (Poisson Zone)	Storms Present
E C Roberts	schooner	Sept. 18, 1872	foundering	unknown	54	X
A H Moss	schooner	Sept. 18, 1872	foundering	unknown	54	X
Guido Pfister	schooner	Oct. 10, 1885	grounding	unknown	44	
H E Runnells	wood lumber hooker	Nov. 26, 1897	grounding	unknown	52	X
Vega	steel steamer	May 18, 1898	grounding	unknown	48	X
Tampa	wood steamer	Nov. 22, 1898	grounding	unknown	30	X
George G. Hadley	wood steamer	June 7, 1902	collision	unknown	44	
Spokane	steel steamer	Oct. 28, 1907	grounding	unknown	37	X
Sacramento	wood steamer	Oct. 14, 1908	collision	unknown	44	
Selden E. Marnin	schooner/barge	Oct. 19, 1908	grounding	unknown	53	X
David B. Meacham	steel steamer	July 28, 1908	grounding	unknown	29	
Vulcan	steel steamer	Oct. 30, 1918	grounding	unknown	52	X

APPENDIX C

APPENDIX C

This appendix comprises the series of tables from chapter 6 which provide raw data on frequency distributions, etc. In order to link these tables with their respective hypotheses they have been numbered in accordance with the hypotheses they concern, rather than in simple numerical sequence. Tables from hypothesis 1 will be listed 1a through 1d, hypothesis 19 as 19a through 19h, and so forth. Some hypotheses will not have tables in this appendix so numerical gaps will be present at some points.

Table 1a. All commodities - salvage and total loss combined

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
5	1	41	2
6	1	43	1
7	1	44	5
10	1	46	1
11	2	47	4
12	2	48	4
13	1	49	1
16	1	52	2
17	1	53	1
19	4	54	12
20	3	55	3
26	1	56	8
28	1	57	6
29	1	58	15
30	2	59	15
32	2	60	1
35	5	62	1
36	15	64	2
37	1	65	1
38	2		

Table 1b. Iron - salvage and total loss combined

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
6	1	47	4
11	1	48	2
19	3	54	5
20	1	55	2
32	1	56	7
35	2	57	2
36	9	58	11
38	1	59	10
41	1	61	1
44	2	64	2
46	1	65	1

Table 1c. Grain - salvage and total loss combined

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
7	1	36	4
10	1	38	1
11	1	41	1
12	1	43	1
16	1	45	1
19	1	54	2
20	2	57	1
26	1	58	1
28	1	59	4
30	1	60	1
32	1	62	1
35	1		

Table 1d. Coal - salvage and total loss combined

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
5	1	48	2
12	1	49	1
13	1	52	2
17	1	53	1
29	1	54	5
30	1	55	1
35	2	56	1
36	2	57	3
37	1	58	2
44	3	59	1

Table 2a. 1855-1879 - Iron

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
54	3	58	4
55	2	59	1
56	3		

Table 2b. 1855-1879 - Grain

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
41	1	58	1
43	1	59	1

Table 2c. 1855-1879 - Coal

<u>Poisson Zone</u>	<u>Frequency</u>
36	1
54	2

Table 2d. 1880-1904 - Iron

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
6	1	47	2
11	1	48	1
35	2	56	3
36	1	57	1
38	1	58	5
41	1	59	6
44	1	62	1
46	1	65	1

Table 2e. 1880-1904 - Grain

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
7	1	54	2
19	1	57	1
20	1	58	1
30	1	59	2
35	1	60	1
36	2	62	1
38	1		

Table 2f. 1880-1904 - Coal

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
30	1	55	1
44	2	57	1
48	2	58	1
52	1	59	1
54	3		

Table 2g. 1905-1929 - Iron

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
19	3	54	2
20	1	56	1
32	1	57	1
36	9	58	1
44	1	59	3
47	2	64	2
48	1		

Table 2h. 1905-1929 - Grain

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
10	1	28	1
11	1	32	1
12	1	36	2
16	1	45	1
20	1	59	1
26	1		

Table 2i. 1905-1920 - Coal

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
5	1	44	1
12	1	49	1
13	1	52	1
17	1	53	1
29	1	56	1
35	2	57	2
36	1	58	1
37	1		

Table 6a. Marquette

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
54	5	59	2
55	2	62	1
56	6	65	1
58	6		

Table 6b. Ashland

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
11	1	47	3
35	2	48	1
36	2	58	2

Table 6c. Two Harbors

<u>Poisson Zone</u>	<u>Frequency</u>
36	1
38	1
57	1
59	1

Table 6d. Duluth/Superior

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
16	1	45	1
19	3	46	1
20	1	47	1
30	1	54	2
32	2	56	1
35	1	57	2
36	7	58	3
38	1	59	3
41	1	60	1
43	1	62	1
44	2	64	2

Table 6e. Port Arthur

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
7	1	20	1
10	1	26	1
11	1	28	1
12	1	59	1

Table 10a. Grounding

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
5	1	44	1
6	1	47	1
7	1	48	2
10	1	49	1
11	1	52	2
19	4	53	1
20	3	54	8
26	1	55	3
28	1	56	6
29	1	57	2
30	2	58	7
35	1	59	4
36	13	62	2
37	1	64	1
43	1		

Table 10b. Foundering

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
11	1	45	1
12	2	46	1
16	1	47	2
17	1	48	2
32	1	54	3
35	4	56	1
36	1	57	3
38	2	58	6
41	1	59	3

Table 10c. Collision

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
13	1	58	1
41	1	59	7
44	4	65	1
56	1		

Table 10d. Fire

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
32	1	58	1
47	1	59	1
54	1	60	1

Table 13a. Schooner

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
35	1	56	1
43	1	58	2
44	1	59	3
54	7	62	1
55	2		

Table 13b. Schooner-barge

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
11	1	53	1
17	1	54	1
32	1	55	1
35	1	57	2
36	2	58	8
38	2	59	1
47	2	65	1
48	2		

Table 13c. Wooden steamer

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
5	1	44	2
11	1	46	1
12	1	47	1
19	1	49	1
26	1	54	1
28	1	56	4
30	1	57	1
32	1	58	5
35	2	59	5
36	3	60	1
41	1	62	1

Table 13d. Steel steamer

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
10	1	44	1
12	1	47	1
13	1	48	2
16	1	52	1
20	2	54	2
29	1	56	1
35	1	57	2
36	6	59	3
37	1	64	2

Table 13e. Miscellaneous vessels

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
6	1	45	1
7	1	52	1
19	3	54	1
20	1	56	1
30	1	57	1
33	1	58	1
36	4	59	3
44	1		

Table 15. Vessel capacity

<u>Year</u>	<u>Tons</u>	<u>Year</u>	<u>Tons</u>	<u>Year</u>	<u>Tons</u>
1855	500	1881	2400	1906	11440
1856	550	1882	3000	1907	12000
1857	600	1883	3215	1908	12065
1858	650	1884	3430	1909	12130
1859	700	1885	3645	1910	12195
1860	750	1886	3860	1911	12260
1861	800	1887	4075	1912	12325
1862	850	1888	4290	1913	12390
1863	900	1889	4505	1914	12455
1864	950	1890	4720	1915	12520
1865	1000	1891	4935	1916	12585
1866	1050	1892	5150	1917	12650
1867	1110	1893	5365	1918	12715
1868	1150	1894	5580	1919	12780
1869	1200	1895	5800	1920	12845
1870	1200	1896	6280	1921	12910
1871	1350	1897	6760	1922	12975
1872	1500	1898	7240	1923	13040
1873	1650	1899	7720	1924	13105
1874	1800	1900	8200	1925	13170
1875	1950	1901	8740	1926	13235
1876	2100	1902	9280	1927	13300
1877	2250	1903	9820	1928	13365
1878	2400	1904	10360	1929	13430
1879	2550	1905	10900	1930	13495
1880	2700				

Table 19a. Total loss

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
6	1	47	3
11	1	48	1
32	1	54	3
35	2	55	1
36	2	56	6
38	1	57	2
41	1	58	11
44	1	59	7
46	1		

Table 19b. Iron - salvage

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
19	3	55	1
20	1	56	1
36	7	59	3
44	1	62	1
47	1	64	2
48	1	65	1
54	2		

Table 19c. Grain - total loss

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
10	1	36	3
11	1	38	1
12	1	41	1
16	1	43	1
19	1	45	1
20	1	57	1
26	1	58	2
28	1	59	3
32	1	62	1

Table 19d. Grain - salvage

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
7	1	36	1
20	1	54	2
30	1	59	1
35	1	60	1

Table 19e. Coal - total loss

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
5	1	49	1
12	1	54	3
13	1	55	1
17	1	56	1
35	2	57	3
36	2	58	2
48	1	59	1

Table 19f. Coal - salvage

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
29	1	48	1
30	1	52	2
37	1	53	1
44	3	54	2

Table 19g. All commodities - total loss

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
5	1	41	2
6	1	43	1
10	1	44	1
11	2	45	1
12	2	46	1
13	1	47	3
16	1	48	2
17	1	49	1
19	1	54	6
20	1	55	2
26	1	56	7
28	1	57	6
32	2	58	15
35	4	59	11
36	7	62	1
38	2		

Table 19h. All commodities - salvage

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
7	1	52	2
19	3	53	1
20	2	54	6
29	1	55	1
30	2	56	1
35	1	59	4
36	8	60	1
37	1	62	1
44	4	64	2
47	1	65	1
48	2		

Conclusion. Iron - storms

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
11	1	48	1
19	2	54	3
20	1	55	2
32	1	56	2
35	2	57	1
36	2	58	9
41	1	62	1
47	3	64	2

Conclusion. Grain - storms

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
10	1	32	1
11	1	36	4
12	1	38	1
16	1	43	1
19	1	54	2
20	2	57	1
26	1	58	1
28	1	59	2
30	1	62	1

Conclusion. Coal - storms

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
5	1	53	1
30	1	54	5
35	2	55	1
36	1	56	1
37	1	57	2
48	1	58	2
49	1	59	2
52	2		

Conclusion. All commodities - storms

<u>Poisson Zone</u>	<u>Frequency</u>	<u>Poisson Zone</u>	<u>Frequency</u>
5	1	41	1
6	1	43	1
10	1	47	3
11	1	48	3
12	1	49	1
16	1	52	2
19	3	53	1
20	3	54	10
26	1	55	3
28	1	56	3
30	2	57	4
32	2	58	11
35	5	59	3
36	7	62	2
37	1	64	2
38	1		

REFERENCES CITED

REFERENCES CITED

- Bald, Frederick E. 1961. Michigan in Four Centuries. Harper, New York.
- Barry, James P. 1973. Ships of the Great Lakes: 300 Years of Navigation. Howell-North Books, Berkeley.
- Bass, George F. 1972. A History of Seafaring based on Underwater Archaeology. Walker & Co., New York.
- Bayer, E. P. 1938. Grading to Cargo Specifications. In Lake Superior Iron Ores, Chris Hickok ed. Lake Superior Iron Ore Assoc., Cleveland.
- Berry, Brian J. and Duane F. Marble eds. 1968. Spatial Analysis: A leader in Statistical Geography. Prentice-Hall, Englewood Cliffs, New Jersey.
- Clarke, David L. 1968. Analytical Archaeology. Methuen, London.
- Dacey, Michael F. 1968. Modified Poisson Probability Law for Point Pattern More Regular Than Random. In Spatial Analysis: A Leader in Statistical Geography, Brian Berry and Duane Marble eds. Prentice-Hall, Englewood Cliffs, New Jersey.
- Doran, J. E. and F. R. Hodson. 1975. Mathematics and Computers in Archaeology. Harvard University Press, Cambridge, Mass.
- Erickson, Bernard E. 1969. The Evolution of Great Lakes Ships. Part II, Inland Seas 25(3):199-212.
- Evans, Henry O. 1942. Iron Pioneer: Henry W. Oliver 1840-1904. E. P. Dutton & Co., New York.
- Garrety, John A. 1971. The American Nation - A History of the United States to 1877. Harper & Row, New York.
- Hatcher, Harlan. 1950. A Century of Iron and Men. Babbs-Merrill Co., New York.
- Heden, Karl. 1966. Directory of Shipwrecks of the Great Lakes. Bruce Humphries, Boston.

- Hickok, Chris N. (ed.) 1938. Lake Superior Iron Ores. The Lake Superior Iron Ore Association, Cleveland.
- Hodder, Ian and Cline Orton. 1976. Spatial Analysis in Archaeology. Cambridge University Press, Cambridge.
- Holland, Francis R. 1972. American Lighthouses - Their Illustrated History Since 1716. Stephen Green Press, Brattleboro, Vt.
- Hulse, Charles A. et al. 1977. Archaeological Survey of Rock Kilns and Finn Hollow (20 AR 10), Alger Co., Michigan. Archaeological Survey Report No. 24, MSU Museum Publication.
- Jarchow, Merrill. 1948. King Wheat. Minnesota History, 29(1):1-28.
- Johnson, Gilbert R. 1948. United States-Canadian Treaties Affecting Great Lakes Commerce and Navigation. Inland Seas 4(2):113-119.
- LaFayette, Kenneth D. 1977. Flaming Brands: Fifty Years of Iron Making in the Upper Peninsula of Michigan 1848-1898. Northern Michigan University Press, Marquette.
- Life Saving Service, United States 1877-1914. Annual Reports, District No. 9.
- Mac Elwee, Roy S. 1921. Economic Aspects of the Great Lakes - St. Lawrence Ship Canal. Ronald Press, New York.
- MacGibbon, Duncan. 1932. The Canadian Grain Trade, Macmillan Co., Toronto.
- Mansfield, J. B. (ed) 1899. History of the Great Lakes. 2 Vols., J. H. Beers & Co., Chicago.
- Mueller, James W. Ed. 1975. Sampling in Archaeology. University of Arizona Press, Tucson.
- Murray, C. B. 1938. Classification and Sampline of Ore. In Lake Superior Iron Ores, Chas. Hickok ed. Lake Superior Iron Ore Assoc., Cleveland.
- Neu, Irene D. 1953. The Building of the Sault Canal 1852-1855. The Mississippi Valley Historical Review, 40(1):25-46.
- Nute, Grace Lee. 1944. Lake Superior. Bobbs-Merrill Co., New York.
- O'Brien, T. Michael. 1976. Guardions of the 8th Sea - A History of the United States Coast Guard on the Great Lakes. U. S. Coast Guard, Washington, D. C.
- Odle, Thomas D. 1951. The American Grain Trade of the Great Lakes, 1825-1873. Part I. Inland Seas 7(4):237-245.

- Odle, Thomas D. 1952a. The American Grain Trade of the Great Lakes, 1825-1873. Part II. Inland Seas 8(1):23-28.
- Odle, Thomas D. 1952b. The American Grain Trade of the Great Lakes, 1825-1873. Part III. Inland Seas 8(2):99-104.
- Odle, Thomas D. 1952c. The American Grain Trade of the Great Lakes, 1825-1873. Part IV. Inland Seas 8(3):177-192.
- Odle, Thomas D. 1952d. The American Grain Trade of the Great Lakes, 1825-1873. Part V. Inland Seas 8(4):248-252.
- Odle, Thomas D. 1953a. The American Grain Trade of the Great Lakes, 1825-1873. Part VI. Inland Seas 9(1):52-58.
- Odle, Thomas D. 1953b. The American Grain Trade of the Great Lakes, 1825-1873. Part VII. Inland Seas 9(2):105-109.
- Odle, Thomas D. 1953c. The American Grain Trade of the Great Lakes, 1825-1873. Part VIII. Inland Seas 9(3):162-168.
- Odle, Thomas D. 1953d. The American Grain Trade of the Great Lakes, 1825-1873. Part IX. Inland Seas 9(4):256-261.
- Parkins, Almon E. 1918. The Historical Geography of Detroit. Michigan Historical Commission, Lansing.
- Reid, J. and M. Schiffer, and J. Neff. 1975. Archaeological Considerations of Intasite Sampling. Sampling in Archaeology, J. Muller ed. 209-216, University of Arizona Press, Tucson.
- Royal Grain Inquiry Commission. 1938. The Report by the Royal Grain Inquiry Commission, Ottawa.
- Royce, Stephen. 1938. Geology of the Iron Ranges: The influence of Geological Conditions on Mining Practice. In Lake Superior Iron Ores, Chas Hickok ed. Lake Superior Iron Ore Assoc., Cleveland.
- Schiffer, Michael B. 1972. Archaeological Context and Systemic Context. American Antiquity 37:156-165.
- Siegel, Sidney. 1956. Nonparametric Statistics for the Behavioral Sciences. McGraw-Hill, New York.
- Sokal, Robert R. and F. Names Rohlf. 1969. Biometry: The principles and practice of statistics in biological research. W. H. Freeman & Co., San Francisco.
- Sommers, Lawrence M. 1977. Atlas of Michigan. Michigan State University Press, East Lansing.
- Steel, Robert G. and James H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York.

- Townsend, Sallie and Virginia Ericson. 1978. Boating Weather. How to Predict It, What to Do About It. David McKay Co., New York.
- United States Coast Guard. 1970. Light List. U. S. Gov. Printing Office, Washington, D.C.
- Willey, Gordon and Jeremy Sabloff. 1974. A History of American Archaeology, Freeman & Co., San Francisco.
- Williamson, Samuel H. 1977. The Growth of the Great Lakes as a Major Transportation Resource, 1870-1911. Research in Economic History 2:173-248.
- Winkelman, A. 1971. Shipping Casualties Resulting in Total Loss on the Great Lakes from 1879-1970.
- Wolff, Julius F. 1969. Before the Days of Radar: Ship Collisions on Lake Superior. Inland Seas 25(2):137-149.
- Wolff, Julius F. 1979. The Shipwrecks of Lake Superior. Lake Superior Marine Museum Assoc., Duluth.
- Wright, Richard J. 1972. Inventory of Shipwrecks within Michigan Coastal Waters. MS on file Northwest Ohio-Great Lakes Research Center, Bowling Green State University.
- Zapfle, Carl and Earle E. Hunner. 1938. Preparation for Market Requirements, Shipment and Reduction. In Lake Superior Iron Ores, Chas. Hickok ed. Lake Superior Iron Ore Assoc., Cleveland.

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