THE ARCHAEOLOGY OF SHORE STRANDED SHIPWRECKS OF SOUTHERN BRAZIL

A Dissertation

by

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ABSTRACT

The Rio Grande do Sul coast, in southern Brazil, is an extensive and scarcely populated sandy shore, nearly 620km long, home of stranded ships representing various periods of navigation in the southwestern Atlantic. Investigations suggest a greater occurrence of maritime accidents in the last 200 years, especially in the 19th century, due to the losses of merchant sailing and steam vessels engaged in newly opened trading routes between Europe, North America, Southern Brazil, and River Plate provinces.

The shipwrecks are found partially buried in the sand, in the surf, near the waterline or near the dunes. The beaches in these areas experience both cyclical (seasonal) and non-cyclical (meteorological) events of natural flooding, burial and exposure, with significant implications for the preservation of the materials studied, as well as for the distribution of artifacts and the interpretation of archaeological data. This dissertation presents our current knowledge regarding stranded shipwrecks in southern Brazil, and discusses its potential contributions to nautical archaeology and shipwreck site formation processes.

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NOMENCLATURE

N, NE, NW	North, northeast, and northwest
E	East
S, SE, SW	South, southeast, southwest
W	West
am	Morning
pm	Afternoon
hs	Hours
GPS	Global Positioning System
HP	High pressure
LP	Low Pressure
RSS	Rio Grande do Sul seashore
SHMB	Subsídios para a História Marítima do Brasil
n	Sample size
km	Kilometers
m	Meters
m^2	Square meters
m/s	Meters per second
mbar	Millibar
3D	Tridimensional
2D	Bi-dimensional
Ø	Diameter
JAN-DEC	Respective months of the year

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1. INTRODUCTION

Brazil was the most important overseas colony of Portugal in the beginning of the 19th century when the Portuguese Royal Family migrated to Brazil, running away from Napoleon's domination of Europe. This event triggered a series of political and economic changes, culminating with the liberalization of colonial seaborne commerce in 1808 and the country's eventual independence in 1822.

By this time, the Atlantic Ocean was already a well-established commercial and cultural venue, where merchant vessels from various parts of the world intertwined goods, peoples and ideas along with the development of modern economics. The opening of Brazilian ports to foreign trade during colonial times hence provided the political conditions for the insertion of the country's port cities into the Atlantic trading networks. In southern Brazil the small port city of Rio Grande would flourish as an important commercial center of Atlantic South America.

The treacherous southern Brazilian coast claimed several ships during this time. The extensive and scarcely populated sandy shore, nearly 620km long, is home of stranded ships representing various periods of navigation in the southwestern Atlantic (Figure 1). Investigations suggest a greater occurrence of maritime accidents in the last 200 years, especially in the 19th century, due to the greater numbers of merchant sailing and steam vessels engaged in the newly opened trading routes between Europe, North America, Southern Brazil, and River Plate provinces.

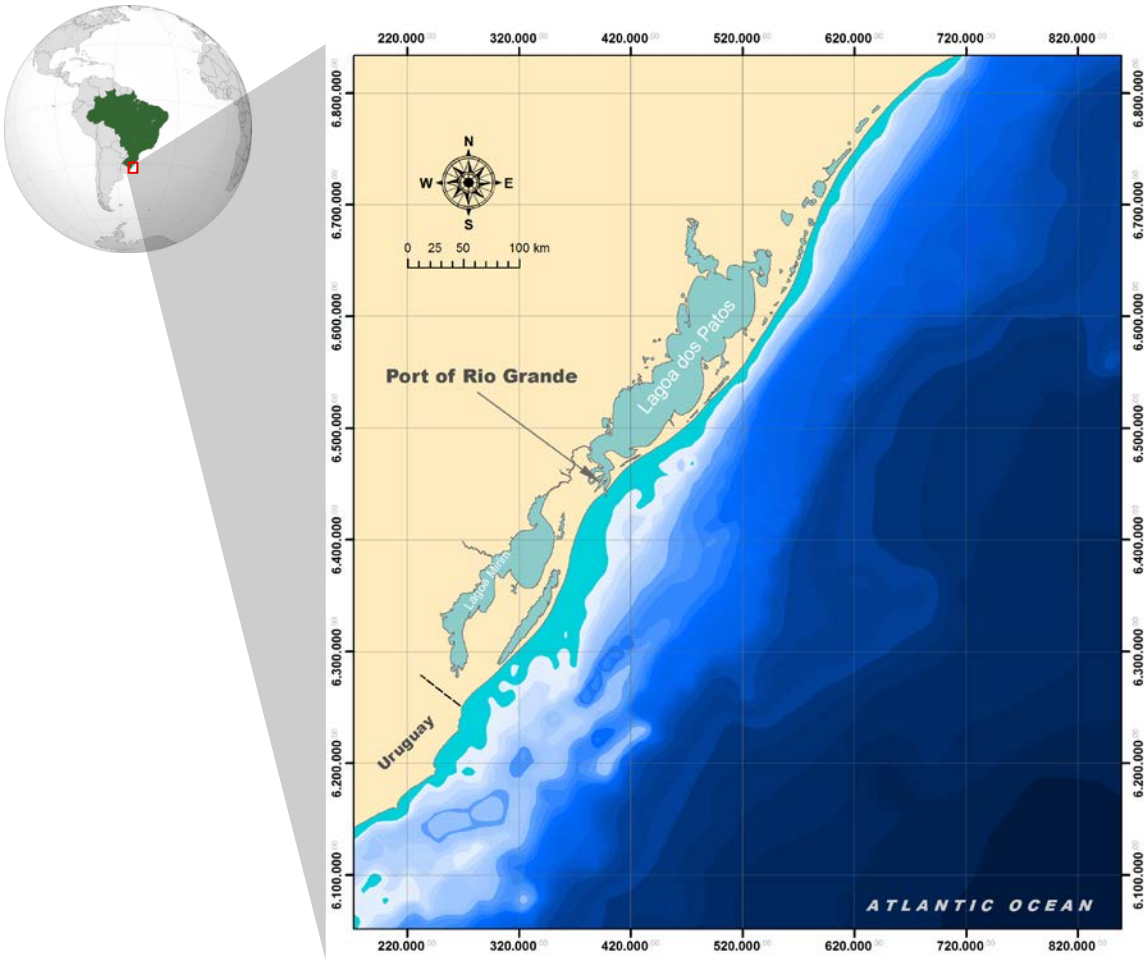

Figure 1. Study area. Coast of Rio Grande Sul, Brazil.

The shipwrecks can be found partially buried in the sand, in the surf, near the waterline or near the dunes. These areas of the beach profile experience an alternation of cyclical (seasonal) and non-cyclical (meteorological) events of natural flooding, burial and exposure, with significant implications for the preservation of the materials studied, as well as for the distribution of artifacts and the interpretation of archaeological data.

In comparison to submerged shipwrecks, beach stranded wreck sites have received little attention in the specialized archaeological literature, regardless to their significance and interpretative potential (Delgado 1984, 1997; Smith et al. 1987; Bright 1993). The goal of this dissertation is to present our current knowledge regarding the stranded shipwrecks in southern Brazil and to discuss their potential contributions to our understanding of nautical archaeology and shipwreck site formation processes.

Section 2 presents a review on the main theoretical and methodological frameworks concerning the archaeology of stranded shipwrecks, focusing on site formation processes in highly dynamic settings. Section 3 provides a background discussion on the main trends of 19th-century nautical technology and Atlantic merchant marine seafaring. Furthermore, the regional maritime history is contextualized in the light of data from shipping and seaborne commerce through the port of Rio Grande during the period.

Section 4 is divided in three parts. First sub-section presents a consolidated report on a database of 240 maritime accidents in the study area during the 19th century, while the second sub-section examines the associations between maritime accidents and regional weather patterns, followed by the reconstruction of two maritime accidents which happened in the study area in 1861 and 2003 as case-studies. The third sub-section, in turn, presents a review on our current knowledge regarding regional beach geomorphology and explores its implications for the study of shore stranded shipwrecks. The section is then concluded with the preliminary report of an excavation carried out in 2013 at the site NAV Lagoa do Peixe.

Section 5 consolidates the main points concerning our current knowledge on the stranded shipwrecks of southern Brazil, and discusses their potential contributions to nautical archaeology and the study of shipwreck site formation processes in highly dynamic depositional settings.

During this research, some difficulties arose relating to the translation of ship types from Portuguese sources into English. Ship types and terminologies do not always translate well when we take in consideration regional peculiarities in rigging and hull denominations, so I opted for leaving ship type names in the language of the consulted source, and prepared an illustrated Portuguese to English glossary in Appendix A with the correspondences explained. Finally, Appendix B provides a summary of 21 shipwreck sites recorded during fieldwork on the coast of Rio Grande do Sul.

2. THE ARCHAEOLOGY OF STRANDED SHIPWRECKS

Stranded shipwreck sites often occur in highly dynamic sedimentary environments, posing major challenges in terms of preservation and coherence of the archaeological data. These sites typically consist of widely scattered materials located either in the intertidal zone or above the high-tide line. Specialized literature has referred to these sites as ‘scattered’ or ‘scrambled’ (Delgado, 1984, 1985, 1997; McNinch et al., 2006; O’Shea, 2002; Russel, 2002; Muckleroy, 1975).

Every archaeological site poses its own set of challenges for the study and interpretation of the material culture therein. As Edward Harris (1989: xi) noted, the particular characteristics of a depositional setting, namely the archaeological record, will depend upon the historical, cultural and environmental circumstances in which it was created. Perhaps the principal contribution to mainstream archaeology from site formation processes theory is that the observed archaeological record is not necessarily a direct expression of past human behavior (see, for example, Schiffer, 1976, 1996).

Keith Muckelroy (1978: 157), concerned with inference problems for shipwreck archaeology, formerly argued along these lines:

> The shipwreck is the event by which highly organized and dynamic assemblages of artifacts are transformed into a static and disorganized state with long-term stability. While the archaeologist must observe this final situation, his interest […] is centered on the former, whose various aspects are only indicated indirectly and partially by the survival material. If the various processes which have intervened between the two states can be identified and described, the researcher can begin to disentangle the evidence he has uncovered.

This attention to problems related to inference from the archaeological record becomes even more critical as we deal with archaeological sites in highly dynamic depositional settings, since materials are continuously being added, removed, and rearranged, such as in the case of beach stranded shipwreck sites. It is assumed in these circumstances that cultural relatedness is too highly variable and does not correlate with spatial proximity, drastically affecting the coherence of the archaeological record.

By definition, an archaeological site is a place which contains, in a more or less preserved state, information about past events and activities embedded in artifacts and their spatial relationships (Willey & Phillips, 1958: 18; Binford, 1964: 431; Burke & Smith, 2004: 63; for a nuanced discussion, see Dunnel, 1992). It relies upon the archaeologist, however, to define an operational unit which accounts for historical and contextual significance. In this study, the underlying unity of analysis is the Rio Grande Sul coastline, taken as archaeological site where each shipwreck represents a depositional event in time and space.

Context refers to the relationships that artifacts and features have to each other and the situation in which they are found. It is the spatial as well as the chronological relationship, established between artifacts on the same site and between different sites within a landscape. At the fundamental level, the context of a find, whether it is an artifact, feature or structure, consists of its surrounding sedimentary matrix, its provenience within it, and its association with other finds (Renfrew & Bahn, 2008: 52-54). Contexts constitute the raw material of archaeological inquires, and it is precisely the importance of context which makes treasure hunting a tragedy.

Concerns with understanding shipwreck site formation have followed the field of shipwreck archaeology since its origins in the 1960s (Dumas, 1962; Bass, 1966). It initially developed around issues of defining shipwreck sites typologies and discussing the coherence of the archaeological record in relation to the physical characteristics of the underwater environment (Dumas, 1962, 1972; Frost, 1962; Muckelroy, 1977).

Due to the nature of incredibly rich shipwreck sites along the Mediterranean coasts, where these 'microcosms' of ancient people have been investigated since the 1960s, the sub-discipline of nautical archaeology had its beginnings associated by general public with the excavation of well-preserved, near-pristine shipwreck sites (see Bass, 1972; 1983). Early publications have somewhat overlooked the significance of shallow and scattered ship remains, due to their presumed lack of coherent information content (Dumas, 1962, 1972; Frost, 1962). French underwater pioneer Frederic Dumas is generally credited with the first contributions to the differentiation between depositional environments, by drawing a distinction between the differential preservation potential in sandy shores, rocky shores, and shores with cliffs (Dumas, 1962: 4-7):

> A flat coastline where the sand descends gently to depth is not promising. Scattered remains will be buried after the ship has been broken by storms and swell. Rocky shores are more likely to retain traces of shipwrecks: parts of the ship or its cargo are preserved in declivities. […] in shallow water the sea breaks everything and the dislocation of a wreck decreases its interest. […] Steep rocky coasts, typical of the northern Mediterranean, produce the best wrecks.

During these formative stages of underwater archaeology, the idea of pristinely preserved 'time-capsules' pervaded the imagination of archaeologists and the general public, supporting the perception of shipwreck archaeology as inherently linked to the

study of unique snapshots of single, dramatic past events frozen in time (see, for example, UNESCO, 1972). In fact, these early works were operating largely under what has been called the 'Pompeii premise' (Ascher, 1961; Binford, 1981). Despite the paramount importance of these works for the development of the shipwreck archaeology, this perspective has somewhat biased the interest of the discipline, relegating the investigation of scattered and less coherent sites to a less important corner of archaeology.

Broader scope studies of the processes affecting the archaeological record first appeared in the work of processualist and behavior archaeologists concerned with the inferential problems of linking the archaeological record to past human behavior, thus inaugurating a new paradigm in the discipline of archaeology (Schiffer, 1972, 1976; Binford, 1981, 1983). Central to site formation theory is the argument that these processes operate in regular and predictable ways, so the knowledge of the factors involved in shaping an observed archaeological record allow archeologists to recognize and work retrospectively to understand behavior patterns as they existed.

Typically identified with the contribution of American archaeologist Michael Schiffer, site formation theory has established a framework for the consideration of cultural and natural processes transforming material culture within archaeological settings (Schiffer, 1972, 1976, 1996; Schiffer and Rathje, 1973). Schiffer observed that artifacts, as well as features and sites, transit between *systemic contexts*, wherein artifacts are part of an ongoing socio-cultural system of manufacture, use, reuse, and discard, and *archaeological contexts*, where those artifacts culturally deposited or lost are no longer

part of an ongoing society. In fact, artifacts can move back and forth within these different contexts during their *life histories*.

Explicit scientifically-oriented, pattern-searching, statistically-laden frameworks in formation processes for the field of maritime archaeology gained prominence with the contributions of Cambridge-trained maritime archaeologist Keith Muckelroy (Muckleroy, 1975, 1978). Working in underwater sites off the coast of Scotland, Muckelroy made a seminal contribution to the interpretation of shipwreck sites by emphasizing shipwreck site formation as a process and highlighting the role of both cultural and natural processes acting as 'extracting filters' and 'scrambling devices'.

Considered the first attempt to develop and apply explicit middle-range theory for maritime archaeology, Muckelroy's conceptualization of shipwreck site formation processes continue to be influential more than 30 years after its publication (Adams, 2009; Harpster, 2009; Gibbs, 2006). He generated more inclusive and comprehensive site classifications than his predecessors, identifying five different classes of survival of archaeological material, ranging from well preserved and coherent remains, to widely scattered, disarticulated sites. Moreover, the author developed the first methodological program for the interpretation of scattered shipwreck sites (see Muckelroy, 1975, 1977 and 1978).

Muckelroy's two stage method discussed in 1975 presented an efficient way to approach scattered wreck remains, relating recording precision and significance of the archaeological material. However, it considers a rather strict definition of site and does not account for contextual relationships when evaluating the site's potential. This has

been somewhat overcome in works dealing with broader concepts for site definition, such as of maritime landscape and shipwreck province (Westerdal, 1992; Duncan, 2000; O'Shea, 2002), where interpretations benefit from an interplay between scales of analysis within regional settings.

Traditionally, most contributions to shipwreck formation processes focus on the physical, biological, chemical and sedimentary factors responsible for shaping the archaeological record (Murphy, 1997; Stewart, 1999; Wheeler, 2002; Quinn et al., 2007). While working along these lines, some researchers have attempted to formulate generalized and universal-like models for shipwreck disintegration, introducing a predictive quantifiable dimension in the study of wreck sites (McCarthy, 1998; Ward & Larcombe, 2002; McNinsh et al., 2006).

Ward et al. (1999), for instance, have used differential calculus and derivatives to pursue a process-oriented, scale independent, model to explain the disintegration of shipwrecks. In another interesting work, O'Shea (2004) applied Bayesian probabilistic approach to assess and quantify the level of confidence that can be attached to the historical identification of scattered wreck sites in the Great Lakes region.

From the late 1980s, however, the interest in cultural factors behind shipwreck distribution and wreck assemblages has grown in the specialized literature. In an influential work, Donna Souza identified a range of cultural pre-depositional behaviors influencing the formation of the archaeological record, such as risk minimization strategies, as well as depositional and post-depositional factors, including jettisoning,

refloating of stranded vessels and salvage choices in Dry Tortugas, Florida (Souza, 1998).

O'Shea (2002), based on a regional survey of shore stranded historical shipwrecks (19th and 20th centuries), and drawing upon analytical categories present on the works of Donna Souza (1998), Michael Schiffer (1987) and David Clarke (1973), proposed a systematic approach for studying the implications of ship construction, use, loss, deposition, and recovery under the so-called formation theory. O'Shea also adapted theories from related disciplines, such as oceanography, geology, zoology and physics to explore very specific empirical data and examine general patterns concerning pre-depositional (systemic context), depositional (shipwrecking) and post-depositional processes (site alteration) in a regional scale.

Stemming from the Australian school of maritime archaeology, other contributions have highlighted several past and present cultural and political instances shaping the archaeological record (McCarthy, 1998; Richards, 2002, 2003, 2004). Nathan Richards (2002), for instance, used historical and archaeological data to analyze the remnants of deliberately abandoned watercraft in Australia, noting how discard and demolition practices were intimately connected to economic trends and technological developments throughout the many phases in the life history of a vessel.

Drawing upon the well-developed literature on disaster studies, Martin Gibbs explored characteristics of shipboard behavior, wreck formation and the 'archaeological signature' of human responses to shipwreck catastrophe as cultural phenomena (Gibbs, 2006). Brad Duncan, another Australian maritime archaeologist, proposed an

interpretative framework based upon the concept of maritime cultural landscape to study how seascapes are shaped through human responses and perception of risk (Duncan, 2000). In the following section, the historic and maritime backgrounds concerning 19th century merchant marine seafaring, both in the Atlantic and in the specific context of the port of Rio Grande, are presented to provide a baseline in support of further examination of stranded shipwrecks on the southern coast of Brazil.

3. HISTORIC AND MARITIME BACKGROUNDS

3.1 Getting aboard a 19th-century Merchantman

In the first decades of the 19th century, the commercial stimulus that followed the prosperity of the industrial core in Europe was boosted by other political and economic conditions which contributed to a period of expansion in opportunities for the Atlantic shipping industry. The end of the Napoleonic Wars (1793-1815), the opening of new markets with the independence of the Spanish colonies (1808-1825) and Brazil (1822), and the lucrative business that emerged with the outlawing of slave trade, all favored investment in shipbuilding and formation of shipping companies at a time when the world's seaborne commerce was still largely propelled by wind and sails (Macgregor, 1984a: 9-11).

It was, however, a period of profound changes in maritime culture. In fact, the modernization of the industrial age, the new forms of labor organization, and the technological advances that revolutionized production processes on land also irreversibly impacted seaborne commerce and transportation technology worldwide, resulting in a fracture in the historical tradition of merchant sailing ships (Greenhill, 1993: 17-19).

On one side of the production chain in the shipping industry was the merchant, who hired a ship owner to transport goods, passengers, etc., in exchange for the payment of freight. At the other end, usually hundreds or thousands of miles away, was the consignee of the cargo, waiting at some trade center on the shores of the Atlantic

basin. In between them, however, an old technological solution in transportation made of 'wooden ships and iron men' stood practically alone until the mid-19th century.

In fact, in despite of the black smoke that started to loom on the horizon, the typical merchant ship at any seaport on the Atlantic shores in the first half of 19th century continued to be the sailing vessel built entirely in wood, rigged with two or three masts, flax or cotton sails, hemp ropes, nails and bolts of iron, copper or bronze and wooden treenails, with load capacity rarely exceeding 500 tons of displacement (Greenhill, 1980: 6; Daubaugh, 1989: 3). In terms of hull construction and rigging, the ships of this period represented the continuation of technological designs and materials for maritime transportation which matured over 300 years of European mercantilist enterprises overseas.

Much like ship design the working relations under which the sailors were making their living in the early 1800s had also been consolidated long before, during the late and post-medieval times. Routine and working discipline were integral parts of the life aboard the 19th century merchantmen, where the master had entire control in regulating the hours of sleep and food, as well as in navigating and working the ship during the voyage. At sea, his authority was summary, and often absolute, so an offender could be punished either by personal chastisement, confinement on board or by being put in irons (Blunt, 1848: 14). In this regard, work relations carried on board merchant vessels were more like slavery than free labor in their character, and discipline aboard derived from military rather than civilian life (Hohman, 1956: 20, Fingard, 1982: 46).

There was still little specialization in the functions on board. A ship of 200 tons, a typical presence in the port of Rio Grande in the first half of the century, would have a crew comprised of a captain, a mate, a cook, four or five sailors, and one or two apprentices between 10 and 15 years old, usually identified by the function they performed on board rather than by their Christian names. Moreover, the technique of navigation was so well established in sea traditions of ship handling that a sailor could shift between ships, trade routes, or vessel nationality and still perform his duties, contributing to the high mobility, cultural hybridity and social alienation experienced by professional sailors.

Since the early 19th century, however, the logistics of seaborne commerce and shipping had benefited from the technological developments of the industrial era. The application of marine steam engines (1807), the use of iron (1840s) and later steel (1870s) in the construction of hulls and machinery, the fitting of screw propellers (late 1830s) and the general use of electricity on board (1870s), among other improvements, were driving the world's shipping industry to a whole different ground (Ville, 1993: 53; Greenhill, 1980: 17-18, 1993: 74 – 93; Macgregor, 1977: 10).

However, the introduction of steam engines and other technological improvements in shipping industry during the 19th century should not be viewed as a linear scheme of technological succession. It was rather a process with its own logic, established in the specific context of 19th-century seafaring technology and cultural tradition. In fact, until about 1890 most of the tonnage shipped worldwide was still in the holds of sailing vessels (Caminha, 1980: 222; Greeenhill, 1980: 5).

Steamships in the early stages of their employment were relatively expensive, with complex machinery of recent development, requiring large supplies of coal for long voyages. It not only considerably reduced their autonomy, but also affected their efficiency as cargo carriers, since fuel occupied a precious cargo space in the holds. The sailing vessels, though generally slower than steam propelled ones, remained in the shipping business mainly due to tradition, simplicity of propulsion principles, and their lower freight rates.

The spirit of the times can be observed in the entries for 'ship' and 'navigation' in the *Dicionário Marítimo do Império Brazileiro* (Santos, 1877: 138-139):

> The steam engine replacing the sail and becoming the main agent of transportation, allows the mariner to overcome the whim of the elements with speed and regularity. And all that, thanks to the improvement of the devices attached to the application of steam, is carried out with fuel economy, and therefore greatly reduced expense. The sailing vessel of today, with progress in shipbuilding, is at the level of steam in everything except speed. If for trade it still remains at an advantage, not as much is true for the navy, where it is banned. [...] The merchant marine took the steam without denigrating the sailing vessel, which arrives later is true, but for less freight.

It is only after the mid-1860s, however, that steam technology started to be competitive in merchant shipping, when the application of screw propellers and the efficient use of iron for the hull structures and machinery joined the engineering development of a more efficient engine. The second half of that century saw the beginning of what maritime historian Basil Greenhill (1980: 6, 30-32) identified as one of the greatest paradoxes in the history of global industrialization.

According to this author, competition with steamers for opportunities in the international freight market during the period of great expansion in the global trade

spurred the merchant sailing vessel to the apex of its development in terms of efficiency and capacity, at a time when the technological solution embodied by sailing ships was already clearly obsolete. Generally speaking, the merchant sailing ship that emerged around the decades of 1850-1875 was larger, with greater cargo capacity and greater sail area than the vessels that crossed the Atlantic in the first half of that century.

One outcome of this era in ship design was the so-called ‘clipper ship’, which appeared as a result of the demand for faster vessels in the mid-19th century, and subsequently improved to compete with steamers in highly profitable routes of the international trade such as the Gold Rush passage from east to west coasts of North America, rounding South America via Cape Horn, or the China Tea Run, around the Cape of Good Hope via southern latitudes. To reach speeds exceeding 15 nautical miles per hour, these vessels typically had an increased total sail area and were captained by daring and skillful masters. In addition, an emphasis on streamlined appearance and fine-lined hulls produced vessels with higher length-to-beam ratios and sharp deadrise, which dramatically improved their hydrodynamic qualities under speed (Macgregor, 1979).

Nevertheless, it is important to bear in mind that at any time the most efficient merchantmen is one that offers the best compromise between three main features: load capacity, speed and operational costs (Greenhill, 1980: 22). The clipper ships, though representing a fine achievement of 19th-century nautical architecture, were decidedly designed for speed at the expense of cargo capacity, rendering them inefficient for all other trades in which high turnover was not the key for profit.

On the other hand, the popularity of barque-rigged merchantmen in the 19th century may represent a more comprehensive example of this chapter in the history of seaborne transportation technology (Figure 2). The combination of fore-and-aft with square sails, such as in barque-rigged vessels, provided captains with a diversified sail plan, thus offering a wider set of options during the passages and favoring an optimal usage of wind at different latitudes and coastal areas (Arlington, 1993: 155-157).

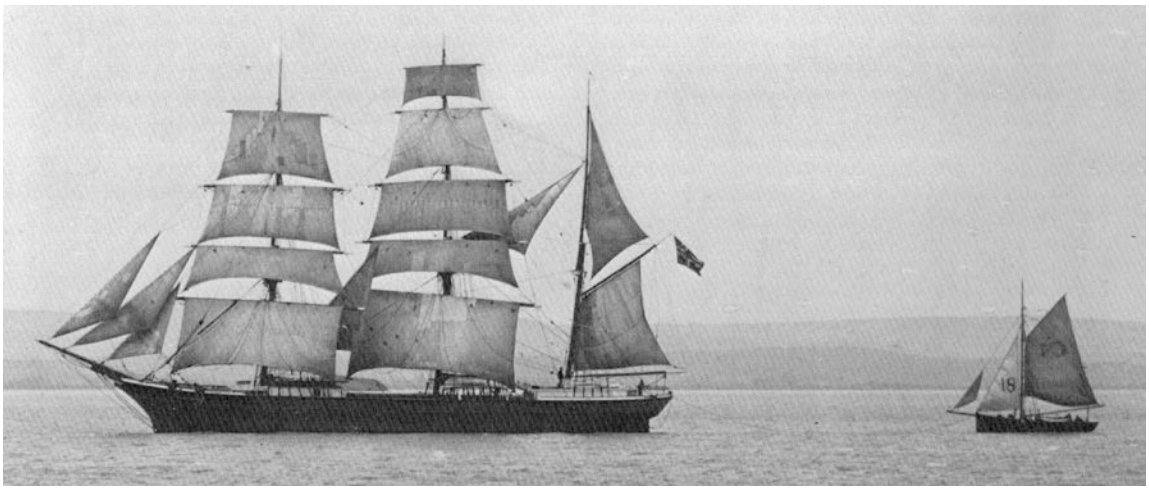

Figure 2. Technically, the three-masted *barca* was a sailing ship in which the fore and main masts were rigged with square sails, while the mizzen was fully fore-and-aft rigged, bending a quadrangular gaff sail on the lower mast and a triangular gaff topsail above (Greenhill, 1993: 10) (Source: Greenhill, 1980: 29).

When compared to the two-masted square-rigged brig, for example, which was a very popular merchantman for open water passages in the first half of the 19th century, the barque rig could be given to a larger and more capacious hull, while avoiding enlarging the spars unduly (Macgregor, 1977: 40; 1984: 29-30). Moreover, the absence

of cumbersome square sails on the barque's mizzen mast turned out to be a sound economy when compared with three-masted ship-rigged vessels, by reducing building, maintenance and manning costs per unit of cargo, with very little difference in performance when compared to the ship rigged vessels (Greenhill and Stonham, 1981: 16).

Square-rigged masts also had their sail plan diversified after the mid-1800s. The large and deep single topsail which evolved to be the workhorse of deep-water vessels in post-medieval seafaring had become exceedingly large in the bigger cargo carriers of the industrial era, thus demanding a great deal of manpower for its handling aloft. Consequently, the advent of more maneuverable double topsails (1840s) and later also double topgallant sails (1870s) may be understood as part of a general technological trend towards more efficient sailing and cargo capabilities with reduced crew requirements (Macgregor, 1977: 12; Crothers, 1997: 456).

In fact, despite the growing demand for larger vessels, the number of crew per tonnage transported sharply declined throughout the Golden Age of Sail. In the mid-17th century, a merchant ship required an average of twelve crew members per 100 tons of cargo, whereas in the 18th century that number had dropped to six crew members per 100 tons, further on reduced to only four in the mid-19th century (Ville, 1987: 94).

Therefore, these new settings for modern seafaring under sail did not represent an altogether new technological solution in itself, but rather the product of centuries of slow developments in sailing ships design further pressed in the middle and later 19th century by the competition with steam-powered vessels. The result was the coexistence of old

seafaring practices and technology at a time when the transition to industrial capitalism was transforming production processes and working relations both on land and at sea (Sager, 1989: 10).

3.2 Southern Brazil and the Atlantic Circuit of Trade and Navigation

Dotted along a great extent in the west margin of the Atlantic rim, the Brazilian main ports until late 18th century were established in the states of Maranhão, Pernambuco, Bahia and Rio de Janeiro. However, the move towards more free trade in the world's oceans, and the internal political and economic situation around the time of Brazil's independence, cleared the way for other port cities to engage in the already well-established Atlantic circuit of trade and navigation. The rise of the port city of Rio Grande in the southernmost part of Brazil may be regarded as a case study for this moment in Atlantic history.

Founded early in the 18th century in the context of the military border disputes between the Portugal and Spain to the south of Brazil, the small village of Rio Grande started the 19th century encouraged by a flourishing beef jerky business, a commodity produced in the so-called *charqueadas* farms situated along tributary rivers in the borderland between Brazil and Uruguay.

The *charqueadas* were slavery-based ranches, dedicated to raising cattle for sun-dried beef, hides, as well as other livestock by-products such as horns, ash, tallow, and hair. At that time, beef jerky was an important source of protein to feed slaves, mainly

directed to the supply of gold mines and sugar-cane plantations in central and northeastern Brazil, but also exported to North America and the Caribbean. The hides, in turn, received good prices when exported to Europe (Osório, 2007).

This business provided yet a valuable economic trade for the employment of foreign and national vessels in route to and from the southern provinces of Brazil. Data from maritime trade between 1816 and 1822, collected by Gonçalves Chaves, a local proprietor, ship owner and politician, attests to the diversification in business relations established through the port city of Rio Grande during this period.

Import and export contracts were signed with various national ports, including Rio de Janeiro, Santos, Bahia, Pernambuco, Santa Catarina, Laguna, Espírito Santo and Maranhão. Foreign contracts were established directly with Montevideo, Buenos Aires and Colonia del Sacramento, in the River Plate region; Guyana, Surinam, and Cuba in the Caribbean Sea; Hamburg, Antwerp, Porto, Lisbon, Guernsey, Marseille, Nantes, Bristol, Gibraltar and Cadiz in Europe; Cape Verde, Angola and Sierra Leone in Africa; and Boston, New York, Salem, Philadelphia, Rhode Island, Charleston, Richmond, Alexandria, New Haven, Newport, Providence and Baltimore in North America (Chaves, 1978: 134 - 174).

In 1823 a group of shareholders and locally established businessmen hired steam powered machinery from the United States to dredge the channel in front of the city's waterfront. The new channel allowed ships of 200 tons or more to enter the harbor, and established the foundation berth of the port of Rio Grande, in the so-called Rua Nova das Flores (Copstein, 1982: 60) (Figure 3).

Figure 3. City of Rio Grande as depicted by Jean Baptiste Debret in the year of 1824, showing the new port facilities (modified from Debret, 1978).

New dredging works were implemented in the 1830s, accompanied by the building of a new customs-house (1832) and the refurbishment of the waterfront street. These improvements, executed at the time when the village was elevated to the status of a city (1835), were vivid signs of the urban modernization triggered by the integration of the country's port cities in the Atlantic circuit of navigation and trade (Torres, 2010).

By the middle of the century, Rio Grande had become an important center for maritime trade in southern South America, receiving approximately 500 merchant vessels per year (Pimentel, 1944: 345-346) (Figure 4). In 1855, a total of 474 merchantmen called at the port of Rio Grande, representing 16 different nationalities, and with a total number of 5,813 crew members circulating in and out the city's waterfront and maritime landscape (Camargo, 1868: annexes).

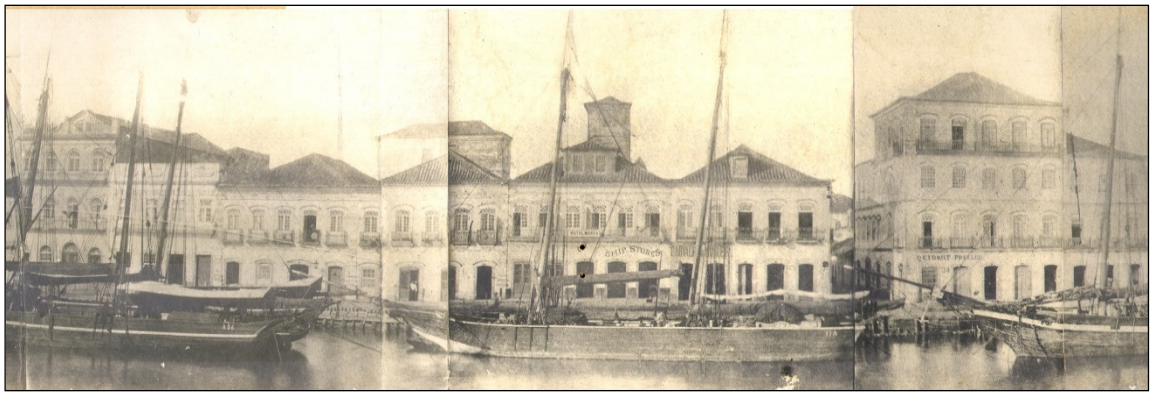

Figure 4. Urban area of Rio Grande by its commercial port c. 1865. (Digital archives. Bibliotheca Rio-grandense).

A look at the nationality of the merchant vessels that called at the port during 1855 shows that there was a predominance of Brazilian vessels in the long-haul movement through the port of Rio Grande, as well as diversified participation by European, North American, and South American ships (Figure 5). Of the total of 474 entered vessels, only 12 were steam powered (all of them Brazilian), against 462 national and foreign sailing vessels (Figure 6).

In terms of ship types, we observe a large predominance of *brigues*, followed by *patachos*, *escunas* e *barcas* (see Appendix A for a glossary of ship types). The tonnage of ships entering the port was also limited to around 200 tons, with the exception of packet steamers (*barcas a vapor*) which, with an average of 450 tons, could safely enter the harbor due to their more flat-bottomed design.

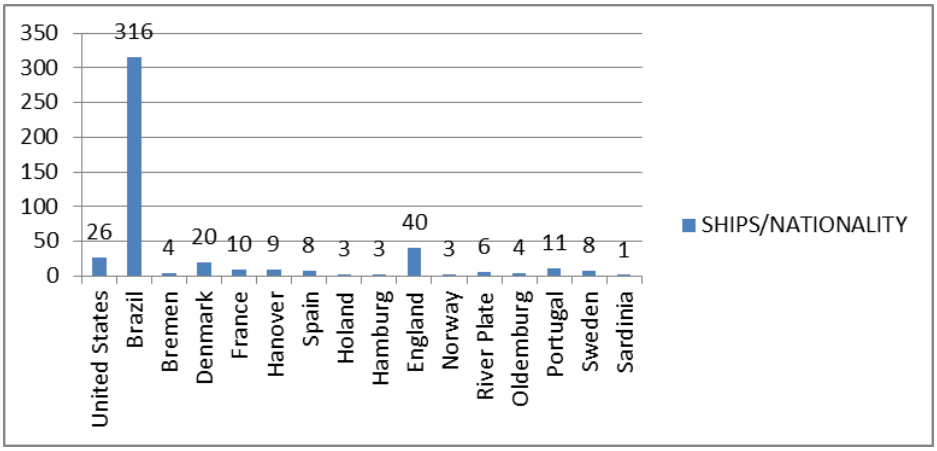

Figure 5. Chart showing the merchant vessels entries by country at the port of Rio Grande in 1855 (Compiled from Camargo, 1868: annexes).

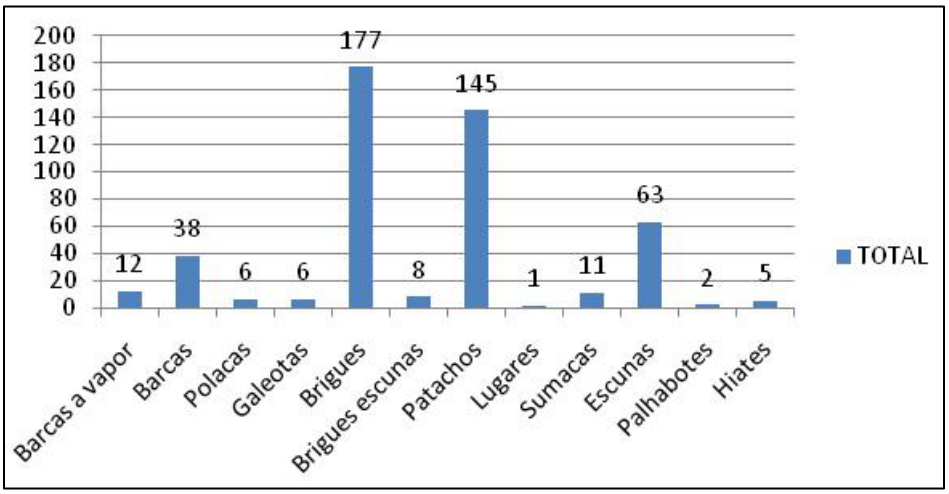

Figure 6. Chart showing the merchant vessels entries by type at the port of Rio Grande in 1855 (Compiled from Camargo, 1868: annexes).

Regarding the composition of the labor force, of the total of 5,813 crew members entering port aboard the 477 merchant vessels in 1855, almost half were foreigners (49%). The Brazilian national crew members (51%) included a large number of slaves

(35%), with the remainder being of free national citizens (16%) (Figure 7). These data draw our attention to the presence of slave sailors in mid-19th century Brazilian society.

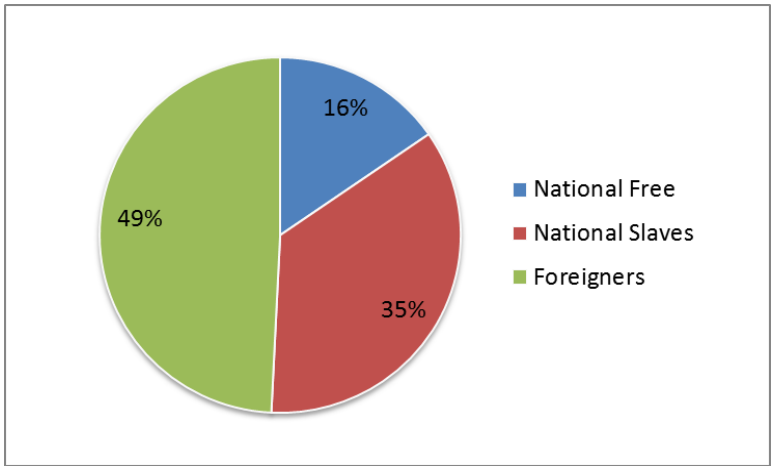

Figure 7. Chart showing composition of the crews entered into the port of Rio Grande in 1855 (Compiled from Camargo, 1868: annexes).

A comparison of tonnage and crew data per type of ship shows that the steamers calling at the port during that year had on average about two or more times the cargo capacity of sailing ships, and that they carried a crew that was twice as large on average (Figure 8). That is, the steamers were bigger and had on board larger crews than the sailing vessels. Moreover, the transit of steam-powered vessels through the port also meant the presence of a qualitatively different crew profile, with knowledge and skills that differed from those traditional to the sea.

Despite the greater size and capacity of steamers, in the 1870s the presence of sailing vessels in the port of Rio Grande was still higher than that of steam-powered vessels. Data from the Pilot Station of the Port of Rio Grande published in Bicalho et al.

(1884: 22 - 23) shows that the total annual movement of sailing vessels surpassed steam-powered vessels by nearly three times in the period between 1873 and 1882, as noted in the chart below (Figure 9).

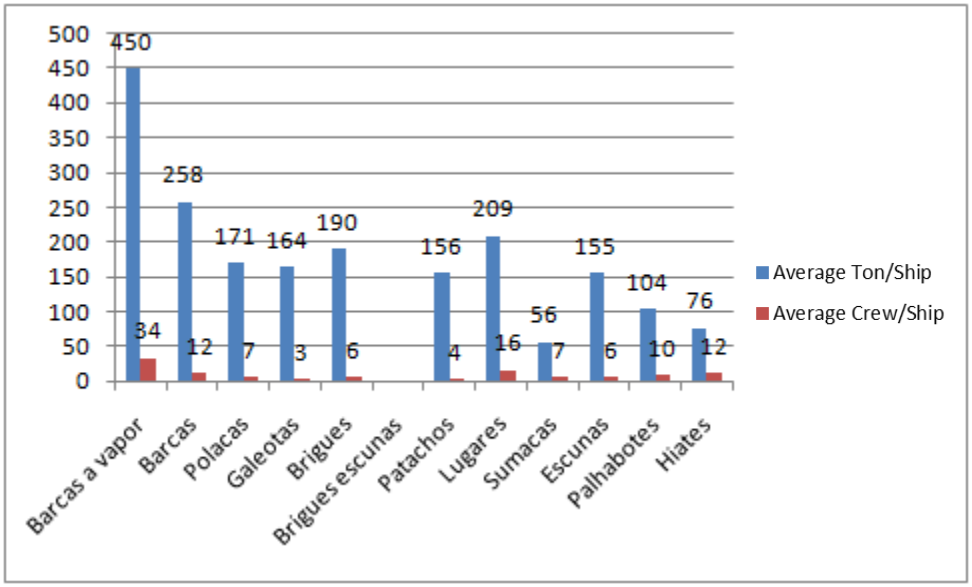

Figure 8. Chart comparing the average tonnage and crew number data per type of merchant ship that entered the port of Rio Grande in 1855 (Compiled from Camargo, 1868: annexes).

Interestingly, the predominance of sailing vessels in the merchant fleet which called at the port between 1873 and 1882 was due to the massive presence of foreign sails (Figure 10). The national fleet, in turn, presented a more balanced profile with respect to the division between steam and sailing vessels, while foreign steamers showed very little presence during that period.

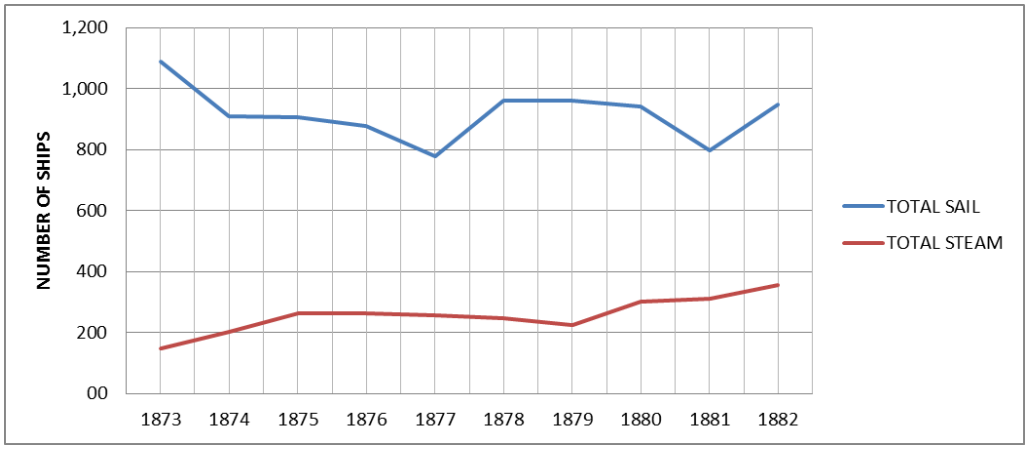

Figure 9. Graph showing total number of sailing and steam ships per year, including vessels entering and leaving the port of Rio Grande between 1873 and 1882 (Compiled from Bicalho, 1884: 22 - 23).

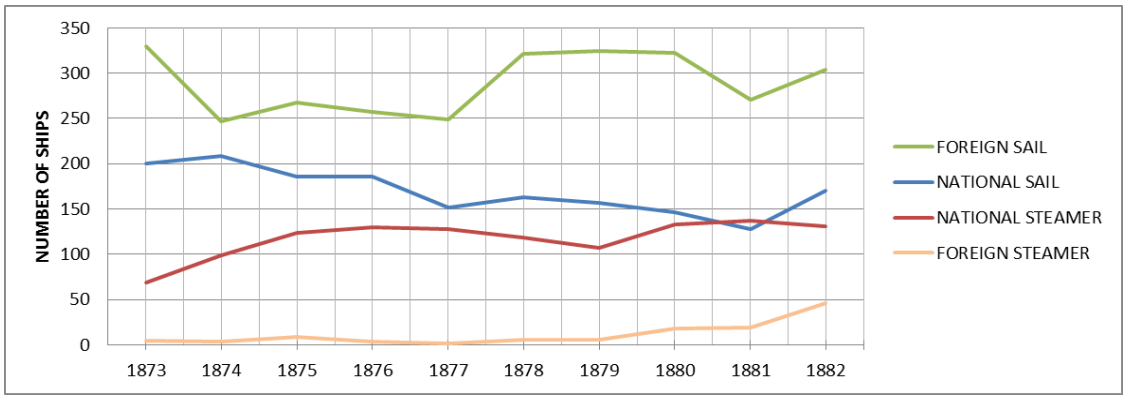

Figure 10. Graph comparing the total number of vessels entering and leaving the port by nationality per type of propulsion between 1873 and 1882 (Compiled from Bicalho 1884: 22 - 23).

In fact, the higher number of national vessels observed in the data for the year 1855 was altered after the late 1860s, when the movement of foreign ships exceeded that of national vessels, followed by a period greater balance in the numbers of foreign and national vessels coming from the Atlantic routes (Figure 11).

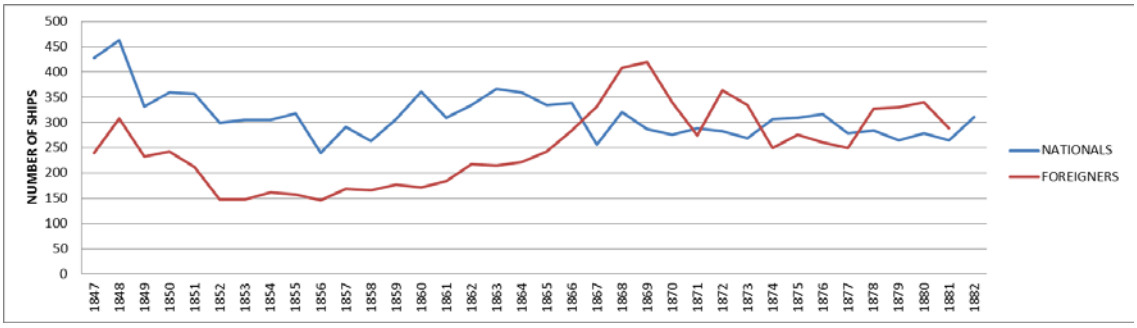

Figure 11. Graph comparing nationalities in the total annual entries through the port of Rio Grande between 1847 and 1882 (Compiled from Pimentel, 1944: 345 - 346).

This balance reflects the end of market restrictions on the Brazilian coastal trade enacted in 1866, which allowed foreign vessels to operate in the national freight market where customs were installed. The deregulation lasted until 1891, when the Republican Constitution reintroduced protectionism in the national shipping service. During the Imperial Government (1822-1889) state subventions had fostered the formation of a significant national merchant fleet, especially with regard to coastal steamships and packets, which grew considerably in the second half of the 19th century. This may partially explain the balance established between the movement of national sailing and steam vessels seen in the graph of figure 10.

There was an operational problem, however, related to access to the Rio Grande harbor. As commerce through the port of Rio Grande grew during the 19th century, the port's only channel silted in, generating complaints from shipmasters to the city's board of trade. According to information collected by the Commission for the Improvement of the Bar and Port of Rio Grande in 1883, the maximum draft in the navigation channel at the inlet, which in the late 18th century had more than 4m, was 3.6m in 1848, 3.5m in

1866, 3.20m in 1875, and 2.70m in 1883 (Bicalho, 1884). Moreover, the channel position was constantly shifting in response to changing hydrographic conditions, making the passage highly unpredictable and exposing the ships to increased risks during the often severe weather conditions (Figure 12).

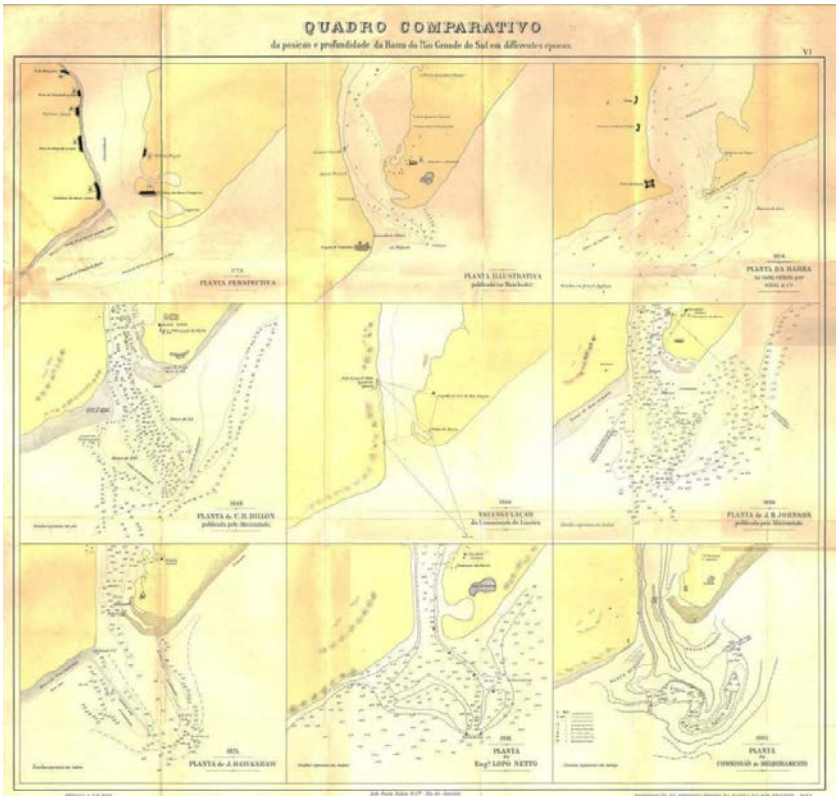

Figure 12. Chart with various surveys of the inlet at the bar, from 1775 until 1883 (Bicalho, 1884: 28).

Perhaps for this reason, by the late 19th century the number of steamers had superseded sailing vessels in the movement of the merchant ships through the port of Rio Grande. In 1900, according to the *Relatórios do Ministério da Indústria, Viação e*

Obras Públicas (1901**:** 593), 243 steam-powered vessels entered the port of Rio Grande, of which the great majority was national, 182, and 61 were from other nationalities. Only 87 sailing vessels entered the Rio Grande port, of which 43 were national, and 44 foreign.

In fact, the government policy to promote national navigation was then strengthened with the creation of the Brazilian Lloyd in 1890, marking the beginning of direct state investment in the merchant fleet (Caminha, 1980: 288). Furthermore, participation from the private sector also increased during the period, with the organization of the Companhia Nacional de Navegação Costeira (1891) and the Companhia de Navegação e Comércio (1905), thus signaling the end of the deepwater merchant ship traffic to the port of Rio Grande (*Relatórios do Ministério da Indústria, Viação e Obras Públicas*, 1911: 292) (Figure 13).

Figure 13. Packet steamer *Itapura* of the Companhia Nacional de Navegação Costeira c. 1895 (Museu Náutico de Rio Grande Digital Archives).

4. THE STRANDED SHIPS OF SOUTHERN BRAZIL

4.1 Shipwreck Database

In the course of this research, an archival investigation was carried out to collect information on shipwrecks and maritime accidents in the study area during the 19th century. A total number of 240 accidents was recorded and entered in an Excel spreadsheet, and later transferred to a database with the fields: DATE, NAME, TYPE, NATIONALITY, ACCIDENT LOCATION, CAUSE, LIFE LOSSES and SOURCE OF INFORMATION.

This information was later transferred to a Geographic Information System (GIS) using software ESRI ArcMap 10.2® (ESRI, 2013)[1]. Essentially, GIS is a software-based information system that enables the storage, display, analysis and management of information from a database within a referenced geographic space. A digital nautical chart issued by the Brazilian Directorate of Hydrography and Navigation (INT 2009: *Do Cabo de Santa Marta Grande ao Arroio Chuí*, scale 1:990,526[2]) (DHN, 2013) was used as a base map, and the shipwrecks were plotted on it and linked to the information from the database (Figure 14). All data containing geographic coordinates in this work was tentatively referred to Datum WGS84, Projection UTM Zone 22S.

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[1] Student trial license provided through Texas A&M University Map & GIS Library.
[2] Available at http://www.mar.mil.br/dhn/chm/box-cartas-raster/raster_disponiveis.html, consulted in 02/12/2011. Electronic charts are available in geoTIFF format, which is a public domain metadata standard which allows georeferencing information to be embedded within a TIFF file.

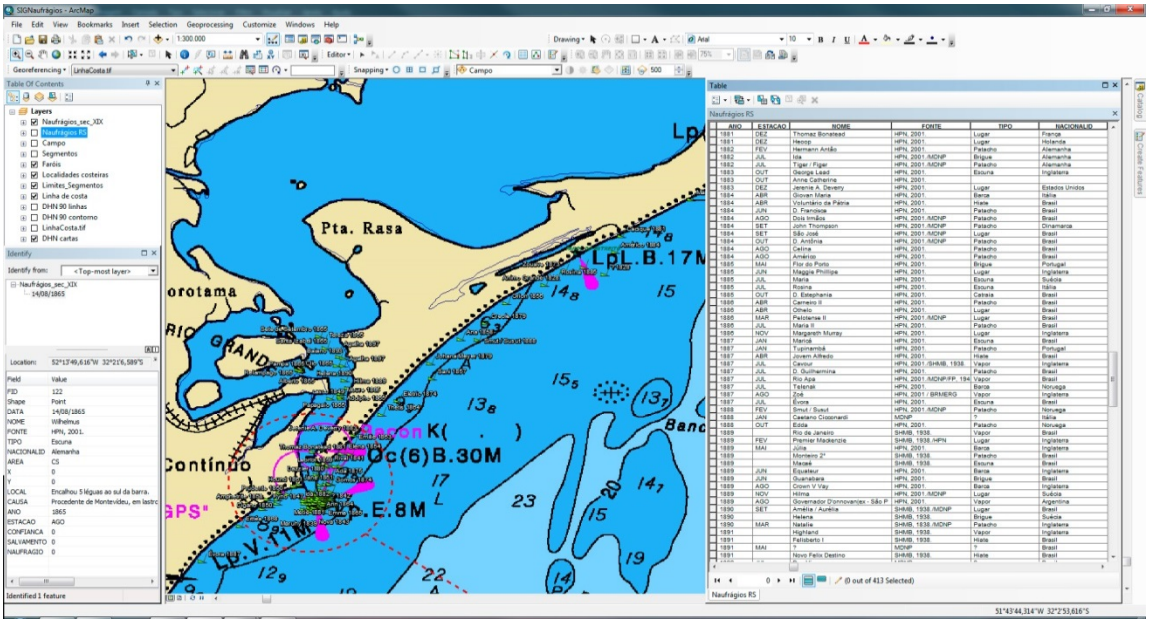

Figure 14. Print screen of a typical working desktop for the GIS built for the Stranded Shipwrecks of Southern Brazil.

Three main archival sources were used in this study, one primary and two secondary sources of information. A summary is presented below:

1. *Mappa Demonstrativo dos Navios Perdidos na Costa e Barra do Rio Grande do Sul*.

Number of entries: 83

Series range (years): 1846 – 1894

Type of source: Primary data. List of maritime accidents organized by the Old Pilotage of the port of Rio Grande. It is more representative of accidents involving vessels approaching the bar, although a number of shipwrecks on the coast are also recorded.

2. *Náufragos e naufrágios no litoral do Rio Grande do Sul* (Alves & Neves, 2001).

Number of entries: 197

Series range (years): 1823 – 1889

Type of source: Secondary data. Based on data collected from contemporary newspapers *Diário do Rio Grande* and *Echo do Sul* for the years 1848 to1889, complemented with limited data available at the *Arquivo Histórico do Rio Grande do Sul* for the years 1822-1847.

3. *Desastres Marítimos no Brasil* (Castro, 1938).

Number of entries: 39

Series range (years): 1839 – 1899

Type of source: Secondary. Study done by Brazilian Navy Office based on a compilation of Navy archives. Not a very systematic survey, but fills well the gap from 1889 to 1899.

It is important to note that the consulted sources all presented data consistency problems, and were used in the present study as a first approach to a quantitative profile of the 19th-century shipwrecks in the area. Nevertheless, a consolidated report with the main characteristics of the data set is presented below.

The first maritime accident reported in the consulted sources happened in 1823 and the last in 1899, thus covering most of 19th century. Out of 240 entries in the shipwreck database, an average of 3.1 shipwrecks per year was found for the entire

period (1823-1899, n=240), with a maximum of 15 shipwrecks in the year 1865. When taking into account only the period when data is denser (1846-1889, n=198), the average rises to 4.5 accidents per year. No shipwrecks were recorded in 21 years, leaving unclear whether no accidents happened in those years, or whether they simply were not recorded in the historical sources consulted. An analysis of the number of accidents over each year suggests that the number of shipwrecks was slightly greater during fall, winter and summer months (56, 55, and 54 accidents, respectively), than in spring (48 accidents) (Figure 15).

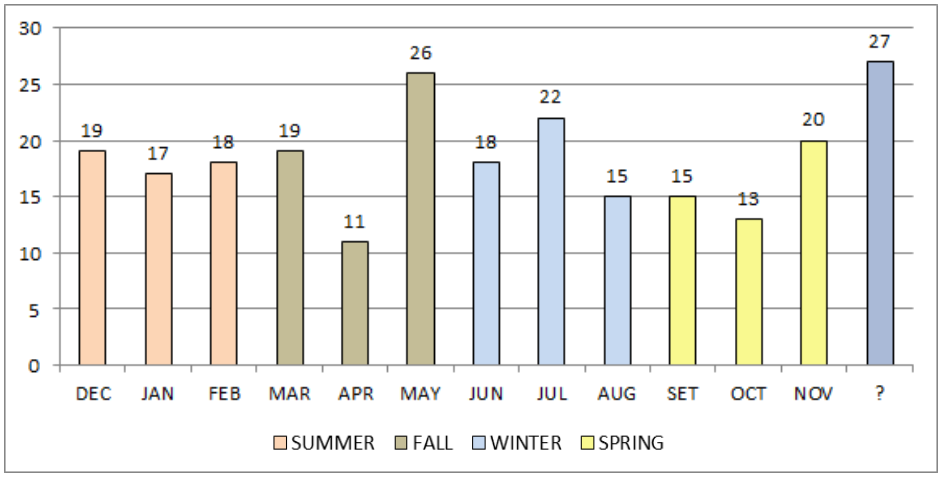

Figure 15. Number of shipwrecks per month/season during the 19th century.

The nation with greater number of ships lost was Brazil, with 34.2%, followed by United Kingdom, 22.5%. In a second group were vessels from German provinces (6.6%), the United States (5.4%), France (5.0%), Holland (4.6%), Italy and Portugal (3.8%), Norway (3.3%), and Denmark (2.9%). A third group was formed by Sweden

(1.7%), Prussia (1.3%), Argentina and Belgium (0.8%), and Chile (0.4%). Lost vessels from non-identified nations totaled 2.9% (Figure 16).

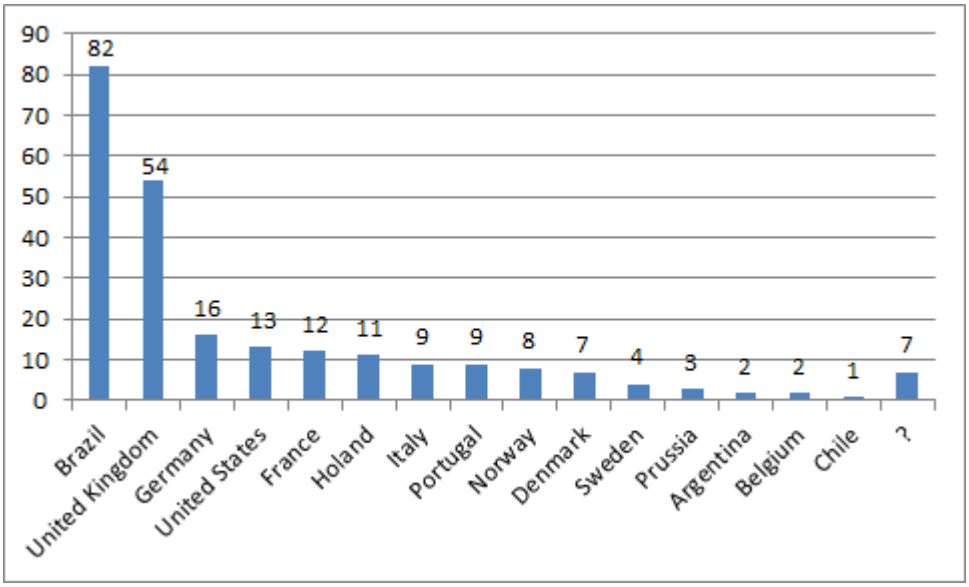

Figure 16. Number of shipwrecks according ship's nationality.

In respect to ship types, the majority of accidents happened with two-masted vessels. *Patachos* accounted for 25.0% of the losses, followed by *brigues*, 17.5%, and *escunas*, 14.6%. *Barcas* and *lúgars* accounted for 7.9% and 6.3%, respectively, while steamers totaled 4.6%, *bergantins* 3.3%, *galeras* 2.5%, *catraias* and *palhabotes* with 2.1%, *hiates* 1.7%, *brigue-barcas*, *botes*, and *sumacas* 1.3%, *launchas* and *polacas* 0.8%, *brigue-escunas* and *cúters* 0.4%, and unknown types 6.3% (Figure 17).

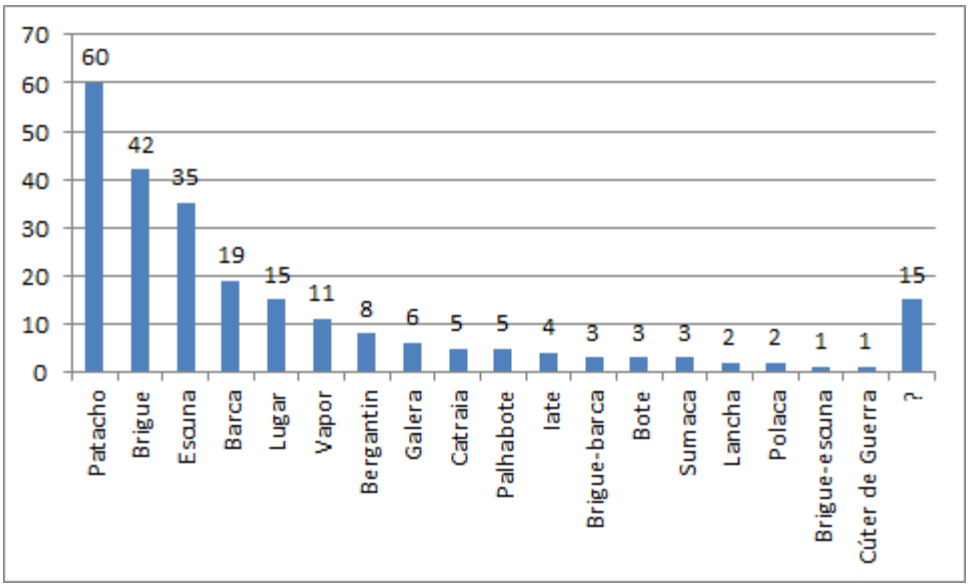

Figure 17. Number of shipwrecks per type of ship.

In order to provide a picture of the spatial distribution of shipwrecks in the study area, the coastline was arbitrarily divided into four segments: Southern, Central, Northern Shores, and the Bar and Port Area (Figures 18 and 19). The overwhelming majority of recorded accidents happened at the bar entrance (n=135, 56.3%), which can be connected to the traffic of ships crossing the bar, either entering or leaving the port area. Considering the shipwrecks that happened along the coast and offshore, 28 accidents (11.7%) happened in the southern shore, whereas 36 (15.0%) occurred in the central shore, and only 8 (3.3%) were reported in the consulted sources to have happened in the northern shore. Shipwrecks in unknown locations summed 33 (13.8%) (Figure 20).

The reported life losses during the period totaled 340 souls, which may be underestimated since, in many cases, nothing was mentioned about the fortune of crew

and passengers. However, just a few accidents accounted for the majority of reported losses. Such were the cases of the packet steamer *Rio Apa* (1887), which disappeared off the bar with 112 people, the Italian *brigue San Jose* (1843) and the Portuguese *barque Eleonor* (1859), both lost on the Rio Grande bar due to a storm, with 27 and 17 losses respectively. Other important disasters were those of the Argentinean steamer *Governador D'Onnovan* (1889) with 23 losses and the English steamer *Powerful* (1865), also 23 losses, at the southern shore.

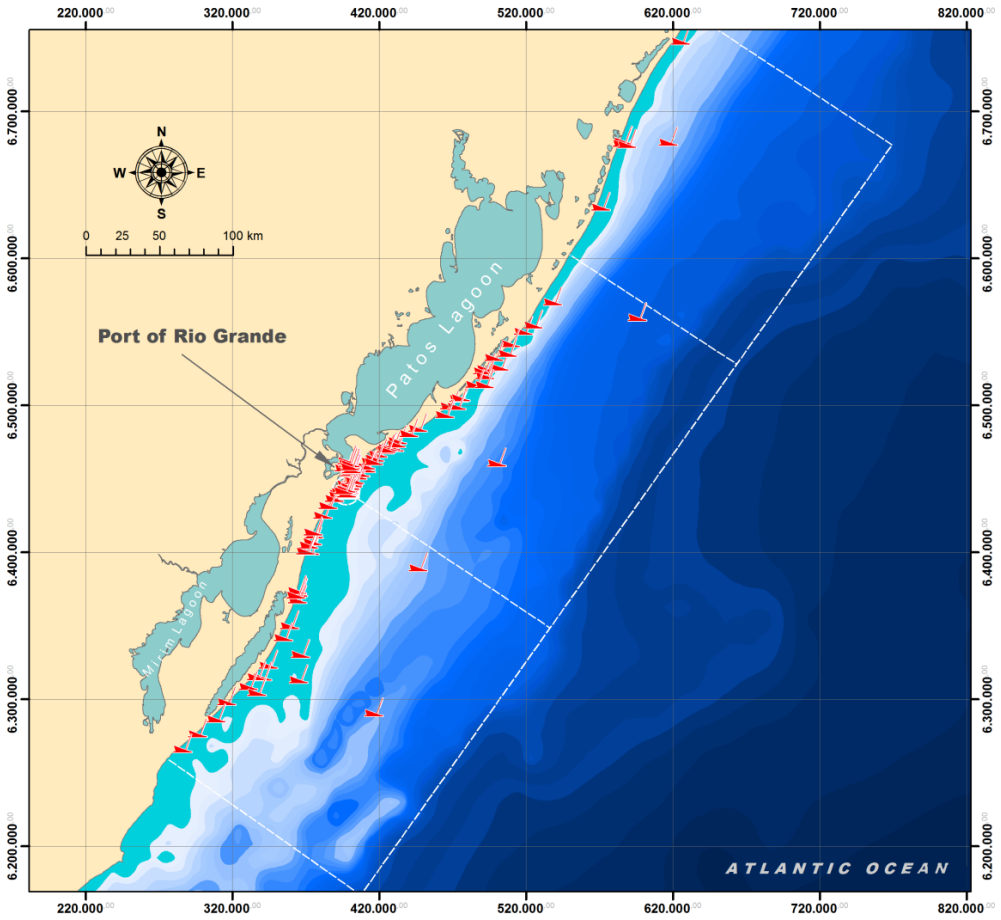

Figure 18. Distribution of shipwrecks along the RSS (Rio Grande do Sul seashore).

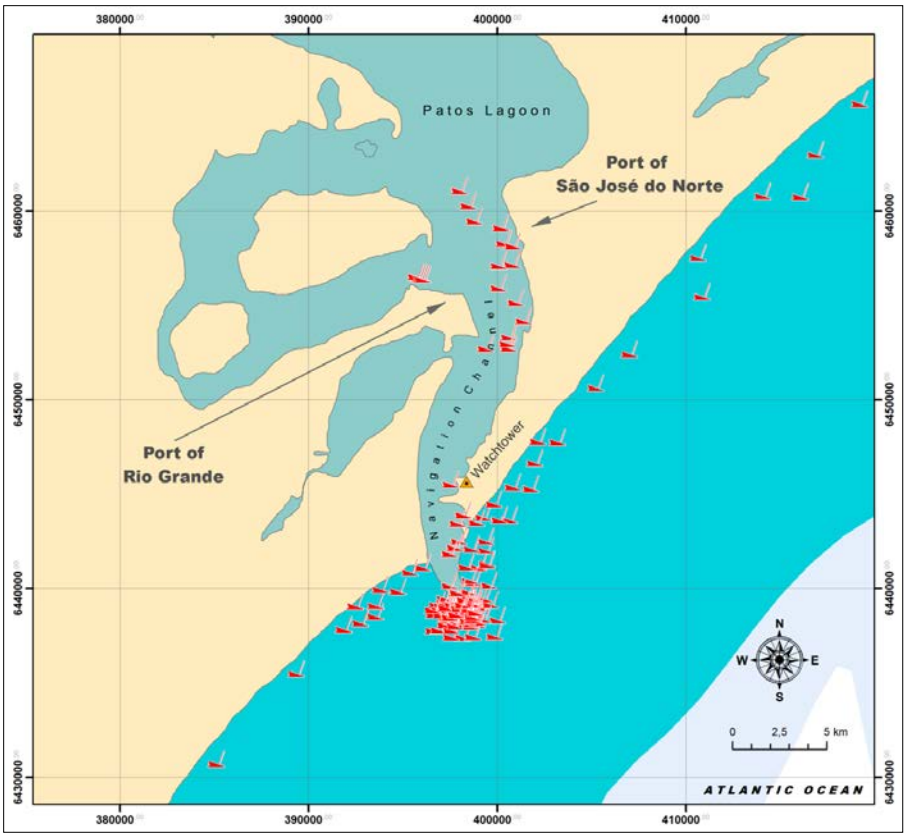

Figure 19. Detail with the distribution of shipwrecks near or at the bar and port area.

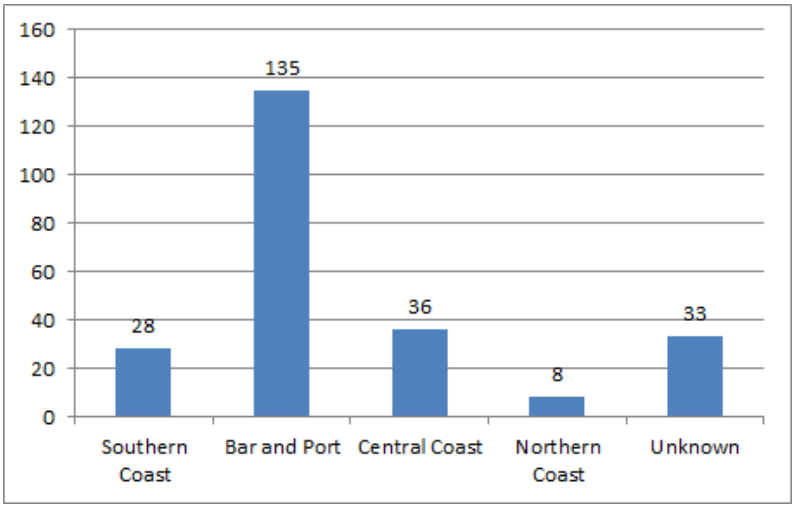

Figure 20. Number of shipwrecks per segment of the coast.

4.2 Shipwrecks and Regional Weather Patterns

The Rio Grande do Sul coast, mostly composed of a low profile, long and monotonous sandy barrier, was feared by early mariners cruising the southwestern Atlantic ship lanes. Scarcely populated and constantly ravaged by strong winds, the southern Brazilian shores had for long been the stage for many unfortunate maritime accidents. Therefore, a basic understanding of regional weather and oceanographic patterns constitutes an important aspect in the investigation of historic navigation and nautical technology.

Winds and currents in the study area are essentially controlled by the action of a zone of high pressure centered at a latitude around 30º S in mid-ocean (South Atlantic Subtropical High – SASH). This high pressure zone forces a large scale counter-clockwise air-water gyre over the South Atlantic Ocean, which is responsible for the year-round dominance in frequency of NE winds. Due to seasonal variations in hemispheric temperature, the SASH oscillates in location and intensity, so that its dominance is stronger in the summer months.

During winter and mid-seasons, the weakening of the SASH favors conditions for transient colder and drier air masses formed in Antarctica to flow over the South America continent at mid-latitudes. This phenomenon originates vigorous counter-clockwise gyres (Migratory Polar Highs - MPH), typically followed by intense winds from W, S, SW and SE quadrants (Tchernia, 1980: 104-105; Peterson & Stramma, 1991; Lobo & Soares, 2007).

The shock of the two air masses with different physical properties, for instance the warmer and more humid SASH and the colder and dryer MPH, often lead to the development of cold fronts over the study area, which are characterized by intense cloud formation and precipitation. With typical SW to NE displacement trajectories along the southwest Atlantic seaboard, these transient lines of instability span approximately 3,000km, vigorously affecting navigation and coastal processes in the study area (Nobre et al., 1986). An average of four to seven cold fronts per month have been observed in the area under analysis, which are more frequent in the austral winter and mid-season months (Nobre et al., 1986; Britto & Saraiva, 1997).

These frontal systems are the atmospheric perturbations of greatest importance to the southern Brazilian climate, and therefore to navigation in the study area. The approach of a cold front is first felt by an intensification of NE winds lasting for 3 to 5 days, followed by a short lull. The temperature rises, barometric pressure falls, and the atmosphere gets charged to the N and NW. As the system develops, dark clouds from W and SW quadrants move over along the coast, followed by thunder, lightning and heavy rain (Figure 21). In the beginning of these storms, the SW winds, regionally called *Pampero*s, are very violent and approach by sudden gusts, which can last for 2 to 3 days (Roteiro Brasil, 1975).

Moreover, extra-tropical cyclones and convective agglomerates spanning over 1,500km, called ‘inverted comma’ systems, can develop in the rear of larger scale frontal systems, when an isolated vortex of cold air is formed and gain cyclonic vorticity in interaction with sea surface temperature (Dall’Antonia Jr., 1991; Castelão & Saraiva,

1999). Additionally, extreme events over the study area have also been associated with instabilities in the subtropical jet stream developed in the lee of the Andes Mountains (Gan, 1992). Moving eastward from the Pacific Ocean, the jet stream is disturbed as it mounts the Andes ridge, interacting with the circulation over South America, potentially generating extra-topical cyclonic vortices with intense low pressure convective systems.

Figure 21. Cloud formation characteristic of approaching cold front, photographed at Cassino Beach, coast of Rio Grande do Sul, 2007.

Gan & Rao (1991) investigated the formation of cyclonic vortices in South America, based on a 10 years data set, and observed two hot spots for their occurrence,

one over the Gulf of San Mathias, Argentina, and another over Uruguay/Rio Grande do Sul border (Figure 22). The authors also found that their occurrence is more intense and frequent over the study area in austral winter and fall (average of 30 vortices/season/year), followed by spring (average of 27 vortices/season/year), and summer (average of 22/season/year). The development of extra-tropical cyclones is frequently associated with wind speeds exceeding 70km/h, abrupt precipitation, and consequent alterations of sea state lasting up to two days, as they follow a general SW to NE to SE track (Saraiva & Silva Dias, 1996).

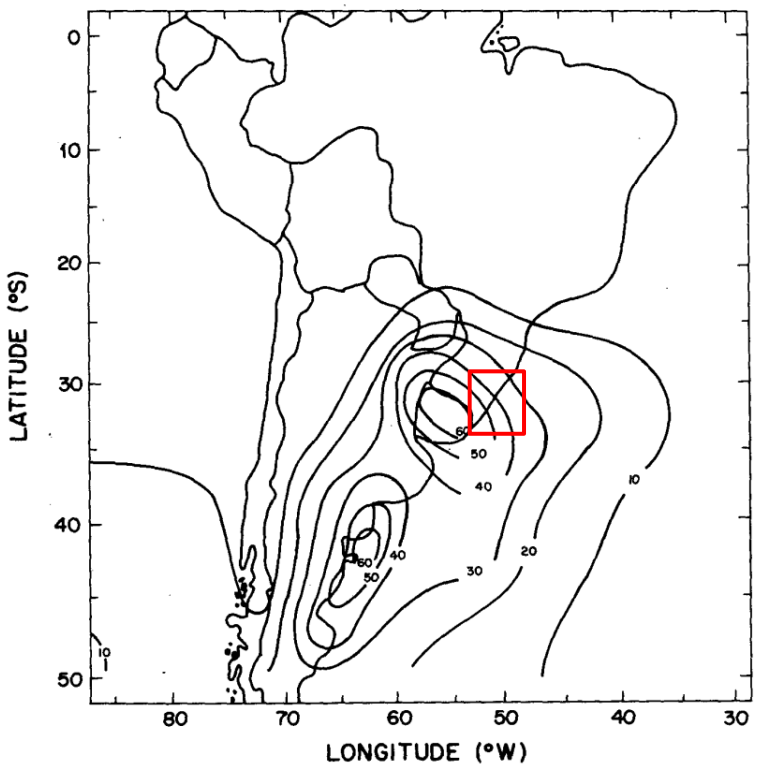

Figure 22. Isolines showing annual distribution of frequency of cyclonic vortices in South America (1979-1988). The red square shows the location of the study area (Modified from Gan & Rao, 1991: 129).

Additionally, extreme events can occur when a particular alignment of pressure centers is established over the study area as a result of a fast intensification of a frontal system coupled with a cyclonic vortex in low atmospheric levels (Marone & Camargo, 1994). The combination of a low pressure center (cyclonic) at sea and a high pressure center (anti-cyclonic) over the continent creates an extensive wind field parallel to the coast for violent winds from the southern quadrants.

These winds often exceed speeds of 70km/h and tend to pile up water against the coast, originating the phenomenon so-called *storm surge*. These storm surges, or the extraordinary high stand of sea level onto the coast, can result from strong storm winds blowing water directly shoreward (SE winds in the Rio Grande do Sul seashore - RSS), or through a physical phenomenon called Ekman transport, which refers to the net flow of water to the left of the wind in the Southern Hemisphere, and to right in the Northern Hemisphere, as a consequence of the earth's rotation (Coriolis deflection) (Figure 23). The effects of a storm surge on the coast will vary depending on the position, intensity and duration of the wind field, but commonly involve the development of steep waves, and strong coastal currents, severe erosion, and the destruction of coastal dunes due to sea set up (Calliari et al., 1998; Parise et al., 2009).

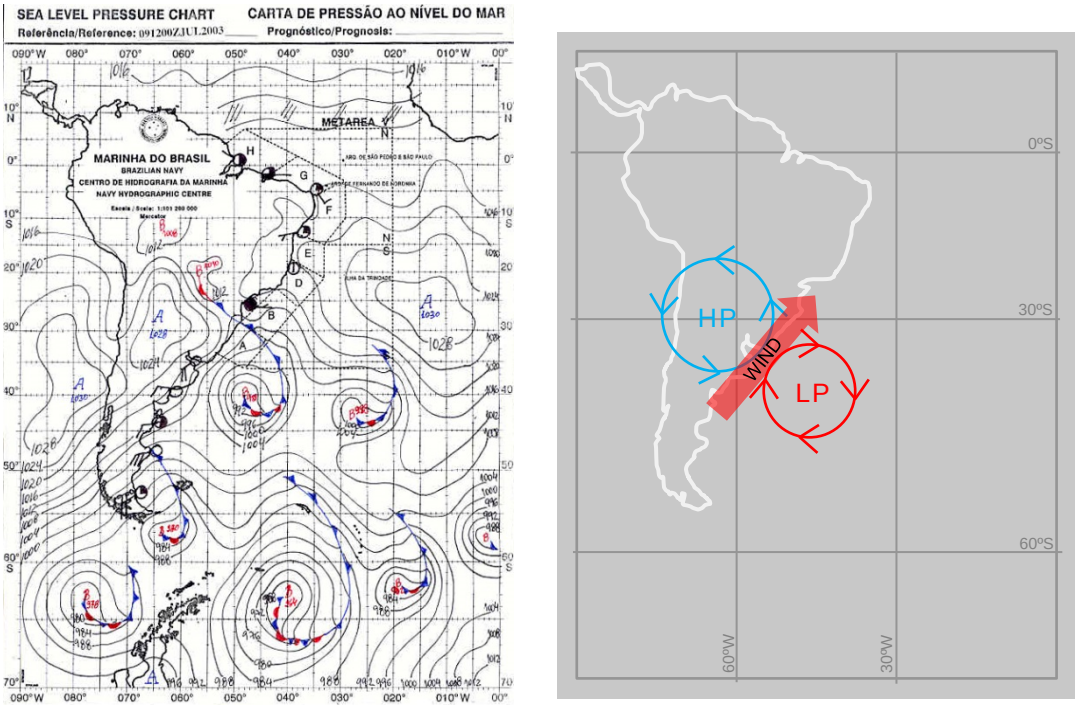

Figure 23. On the left, synoptic chart with the configuration of pressure centers over South America in July 9, 2003 @12:00 GMT. On the right, schematic representation of high and low pressure centers (HP and LP, respectively), and the wind fetch over the study area (Source: modified from http://www.mar.mil.br/dhn/chm/meteo/prev/cartas/cartas.htm).

Incident sea and swell waves generated in the southwest Atlantic typically enter the continental shelf from SE and ENE directions, showing annual average significant wave height of 1.5m. Much higher waves follow storms, and deep water wave heights from the southern quadrant frequently exceed 4.0m during winter months (Motta, 1969; Coli, 1994). Machado (2013) studied the wave regime off the RSS and concluded that it presents two distinct regimes. The first corresponds to sea waves from ESE caused by strong winds generated in or near the coastal zone, and the second to swell or storm waves travelling from SSE. The highest significant wave measured during the period studied was 5.5m, and the maximum wave recorded was 7.6m high. A significant

average height of 1.2m, and a maximum of 2.0m have been observed. The astronomical tide along the Rio Grande do Sul is insignificant, the mean annual daily range being less than 0.5m (Garcia, 1997).

The importance of environmental energy for coastal navigation cannot be underestimated. However, unlike the popular common belief, shipwrecks seldom occur solely because of environmental factors, being more often the result of combined causal effects. From an anthropological standpoint, the wrecking process can be described as chain of events in which external or internal factors force contingent decisions and actions upon those involved, ultimately causing the ship's loss. Therefore, it is assumed here that this chain of decisions and actions unfolds within marked cultural, technological, and historical frameworks, thus becoming a means of access to past human behavior.

In order to better explore this idea, two case-studies of stranding events which took place in the southern Brazilian shores are presented below, one being contemporary to the investigated period (1861), and another examining to a more modern event (2003), for which more information was available, thus allowing for useful analogies.

4.2.1 The Cases of British *barca Prince of Wales*, *patacho Hound*, and Brazilian *brigue Guahyba* (May and June, 1861).

During the months of May and June, 1861, a powerful weather system passed over the southwest Atlantic seaboard, lasting approximately 23 days, and resulting in the loss of at least three merchant vessels on the coast of Rio Grande do Sul. The case was reconstructed based on the news published in the local newspaper *O Comercial* from May 29 to Jun 29, containing a summary of daily reports on the conditions at the bar, relayed from the pilot station to the newspaper headquarters in town by the port's telegraphic system.

On May 29, the day began with fair winds blowing from NE to ENE quadrants. Swell waves were rolling over the shoals at the bar. Water depth in the inlet's deepest channel was sounded by the pilots at 2.85m and 3.20m (Figure 24). The pilots stationed in the watchtower had hoisted call signals for ships drawing up to minimum draft to leave under sail, since water was ebbing in the inlet, but no ship could enter the whole day. The English *patacho Hound*, drawing 3.3m, was seen anchored outside the bar, with pilot aboard, waiting for the call from the tower to tack in.

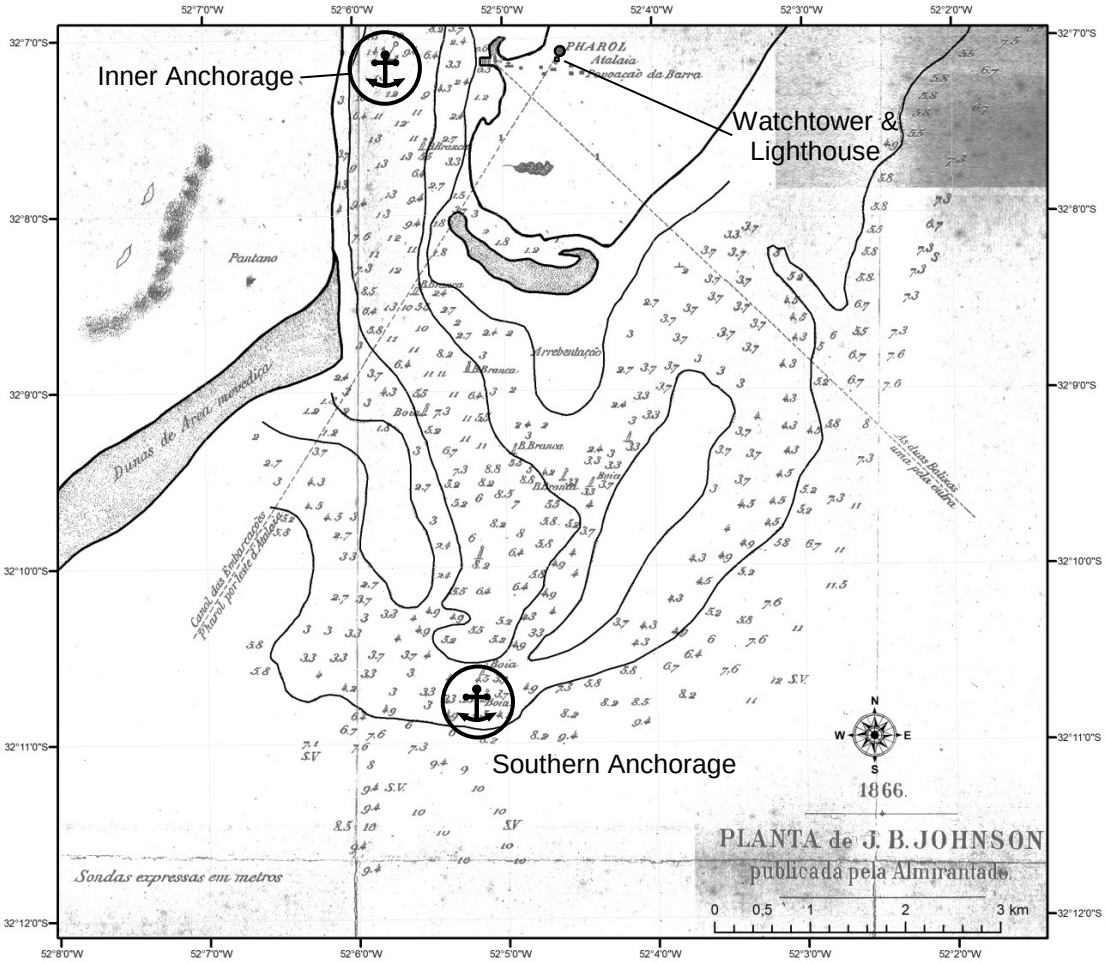

Figure 24. Bathymetric chart of the bar showing the position of the channel, sand banks, anchorages, the watchtower, and the lighthouse (Source: modified from Johnson, 1866).

The next day dawned cloudy, with variable fresh breezes blowing from N to ENE. The sea was calm in the shoals and the channel low in water, due to an ebb current pulling strongly in the inlet. The pilots aboard the *catraia*, or surf boat[3], sounded the same 2.85m and 3.20m for the shallowest depths in the main channel (Figure 25).

[3] The pilot surf's boat is called in Portuguese *catraia*. According to the *Diccionário Marítimo Brazileiro* (Santos, 1877: 50), *catraia* (skiff or pilot surf boat) was a small boat, strongly built, with no transom, employed in the port service, fisheries and bar pilotages. See Appendix A for reference on ship types translation.

Signals were made for ships drawing the minimum draft to enter or leave under tow by the steamer *Proteção*. Six ships were then seen waiting off the bar, including the *patacho Hound*, and the *brigue Mafra*, drawing 3.20m, which had signaled with a leaking hull.

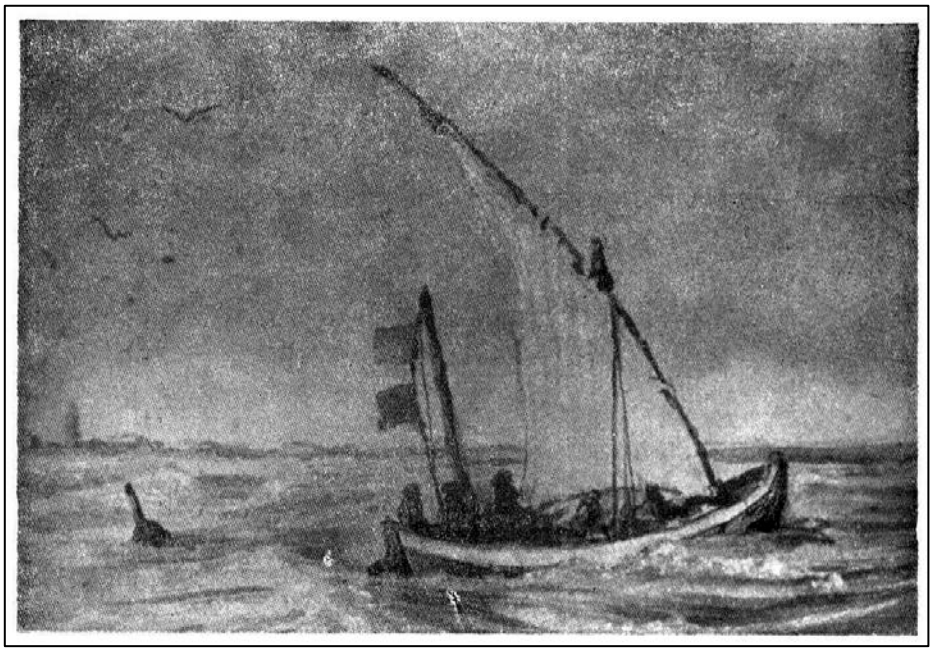

Figure 25: The pilot surf boat at station in the Rio Grande bar with its characteristic flagstaff astern. The watchtower can be seen in the background (left). Watercolor from William Lloyd painted in 1873 (In: Barreto, 1976: 833).

An American *patacho* drawing 3.0m was seen at around 5pm tacking off approximately 6 miles (11km) away, hoisting its national flag at half-mast in request for assistance. Another *patacho* of unknown nationality drawing 3.5m was seen tacking off 8 miles (14km) to the SSE. The *brigue Ligeiro* drawing 2.50m, was sighted waiting at

anchor 7 miles (13km) to the E, and an *escuna*, presumed to be English, was seen tacking off with signals indicating it had a 3.0m draft.

On May 31 there were no entries or departures in the morning, due to a heavy fog coming from the south, which announced the approach of a cold front. Around 4pm the fog dissipated temporarily and the pilots stationed in the watchtower could see that bar was calm. They promptly hoisted signals for entries under tow for ships drawing up to 3.2m, and departures for 3.0m. The wind was now fair and had turned variable blowing from SW to SSE. The *Hound* was spotted waiting at the southern anchorage. The thick fog soon returned, ending the work of the tow steamer and the pilot's surf boat. No ships could be guided in or out. The six ships sighted outside the day before were still tacking or lying at anchor, and few others were waiting in the inside anchorage for signals to leave. The tide in the inlet had ebbed strongly until noon, and then slacked.

The sea was high and the water piled up on the shoals in the morning of June 1. Fresh winds were blowing from ENE to ESE. The pilots aboard the surf boat sounded between 2.8m and 3.2m in the channel. The surf boat and the tow steamer were in activity the whole day, but no ship could be guided in. There were now eight vessels waiting at the southern anchorage demanding to enter: Three Brazilian *brigue*s, the Portuguese *escuna Lima*, a Danish *escuna* drawing 3.1m, and another one which did not hoist its colors. The *Hound* and another English *brigue* drawing 3.1m were seen tacking off the coast. Eleven ships were waiting for signs to leave at the inner anchorage.

After midnight, gale force winds blew from the S to SE quadrants. The passage of the bar was impracticable, with waves breaking all along the coast. The wind then

turned to SSW fresh in the morning, with heavy showers alternating with clear weather occasionally, indicating an intensification of the cold front. The tide in the channel was flooding strong, and seven ships could be seen outside at the southern anchorage. The *Lima* was spotted tacking off under sail to bear the storm. The surf boats were on standby the whole day. The tow steamer made the move to reach the bar a few times but had to return helplessly.

The traffic at the bar remained impracticable the whole day on June 3, with the tide flooding in, and winds blowing from WSW. The weather was foggy, with regular showers throughout the day. Eight ships were sighted outside, seven at anchor plus the *escuna Lima*, still tacking under sail to the SE. The same ships remained in the inside anchorage. Notwithstanding the harsh weather, the pilot's surf boats were kept permanently on standby.

On June 4 the bar was still impracticable for navigation, with a strong flood tide and heavy skies. Variable winds were blowing from SW to WSW quadrants. By then, 16 ships had already cleared their customs' papers and were waiting inside the anchorage for signals to leave, while six vessels were seen at the southern anchorage outside, holding fast in the inclement weather.

Next day began with a light breeze blowing from WSW to S quadrants, water high and flood tide in the inlet. The tow steamer *Proteção* approached the shoals, but did not cross them and was unable to reach the *Hound*, which had hoisted her colors at half-mast signaling the need for ground tackle and supplies. The condition at the bar

remained rough, with a great number of ships at anchor both inside and out unable to cross the inlet.

On June 6, despite the calmer weather experienced during the day, at dusk gossip spread through town, speculating about the loss of *brigue Guahyba* somewhere to the north of the bar. Sadly, the news was later confirmed in the Saturday edition of the local newspaper (*O Comercial*, June 8, 1861): "*Shipwreck: Unfortunately, the loss of Brazilian brigue Guahyba was confirmed. Captain Francisco Paulino da Silva. The captain and 11 seamen survived. Died the negro cook and the passenger José dos Reis, Portuguese*."

A report from the pilotage station, addressed to the city's Customs and Board of Trade office indicated that the ship was lost during the night of June 1, due to the strong SE gale which blew hard after midnight. The *brigue* had left Rio de Janeiro on May 19, loaded with sugar, rice, olives, wheat flour, pasta, and other general cargo. The *Guahyba* ran aground on the beach 30km south of the village of Mostardas, near the Lagoa do Peixe inlet.

According to the report, wreckers were plundering the ship, hauling the cargo away overland before the captain or crew could stop the looting, since they were all in a weakened condition. In the face of this situation, the chief inspector of the Customs branch in the nearby city of São José do Norte sent a party of three guards by land to inspect the location of the accident and oversee the salvage operations.

Around 10pm winds from the southern sector picked up again, making the citizens worried for the fortune of the ships at the anchorage. On the morning of June 7

the telegraph passed news of a second shipwreck. A *patacho* had run aground during the night on the beach to the SW of the bar.

The captain of the lost ship arrived in town around 2:30pm and reported that it was the English *patacho Hound*, coming from Lisbon, 66 days, with cargo of salt consigned to Mrs. J. C. Wigg & Co. The ship went adrift after losing her ground tackle in consequence of the gale force winds that blew during the night, forcing the captain to intentionally run it aground. The crew was rescued in the jolly-boat and no lives were lost.

The bar was still very rough in the morning, with strong variable winds from ESE to SSE. The water in the inlet was low, rising up in the afternoon. Ten vessels were now seen outside, having endured the gales. The group included those previously mentioned, plus the *barca Santa Maria Boa Sorte*, the *palhabote Superior*, drawing 2.5m, the Brazilian *patacho Alexandrina*, and the English *lugar Kelton*. At the anchorage inside, twelve ships were seen waiting for signals to leave.

On June 8 the sea continued very rough and passage of the bar was still impracticable due to a constant SE wind blowing perpendicular to shore. Dense fog was filling in the atmosphere, with quick showers in the afternoon. The sea was high all along the coast. Five ships were now seen tacking and five other at anchor outside. Fourteen ships were at anchor inside, sustaining damage to their hulls, sails and rigging.

The next day at dawn the situation on the bar was still rough, with winds blowing constantly from the ESE quadrant. The sea receded a little bit, and the tide was ebbing on the bar, hence the tow steamer *Proteção* went out and managed to deliver supplies to

the English *brigue Annie Walker*, which needed ground tackle, to the Brazilian *brigue Prazeres*, in need of a bowsprit and hawsers, and to the *patacho Alexandrina*, which was leaking water and missing a boom. There were now thirteen ships outside and fourteen inside.

On June 10 the bar was still impracticable. The telegraph station at the watchtower communicated signals with the ships outside, but they were recognized only by few Brazilian captains, since most of the foreign ship masters did not have the handbook for the System of Telegraphic Signals[4] in use in the port of Rio Grande pilotage since 1848. During most of the day the pilots at the watchtower kept flags in the telegraph for numeral "9", signaling the ships to "*anchor to the south, in 6 or 8 fathoms of water*."[5]

The sea continued rough the next morning, with high swells rolling in over the shoals. The water in the inlet was low, having stopped running around 4pm, followed by strong ebb tide. By then, twelve ships were seen outside, including the *escuna*s *Sea Nymph*, loaded with salt from Cadiz to Proudfoot & Co., and *Fanny Sermes* with 57 immigrants, *lugar Palma* with salt to Kohler & Co., the already mentioned *Kelton*, and the *palhabote Mary Greenwich*, carrying assorted cargo from Boston to Huch & Co.. Ground tackle was needed by the English *brigue Ann Walker*, the *barca Santa Maria*

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[4] The telegraphic system introduced in 1848 allowed the conveyance of more elaborate messages in the communication between the pilot-station and demanding vessels, by means of combining blue balloons and blue pennants (Vereker, 1860: 71-79).
[5] 11 to 14.5 meters.

Boa Sorte, and the *brigue Feliz Americano*. The Brazilian *patacho Arroio Grande*, the *brigue Sequeira*, and the *Feliz Americano* received water and foodstuff.

On June 13 public attention was called to the arrival of Bento Venâncio Soares, resident of Tahim, communicating the appearance of four dead bodies on the beach to the south, including a woman. A jolly-boat and many barrels and sacks had also washed ashore. The people in town were filled with consternation.

In the next day, news from the northern shore informed the townspeople that the *brigue Guahyba* was seen broken up on the beach, and its "[…] *captain and crew were behaving bravely, stacking up everything that was jettisoned on the beach and, with great effort, had salvaged the rigging*." The Customs inspector, at the time of his trip to the wreck site, collected 222 barrels of wheat flour, two small barrels of olives, one piece of *cairo* cable, two lower masts, two topmasts, six yards, one gaff-top, one try-mast, and one bowsprit, one jib-boom, among other things.

On June 15 the weather finally improved and the movement of vessels crossing the bar started to normalize. However, more news confirmed previous concerns, and another ship had run aground on the beach to the south. It was the English *barca Prince of Wales*, coming from Glasgow with cloth, coal, and assorted cargo bound to the River Plate. It had run aground during the SE gale that caused the *Hound* to succumb. According to news published in the newspaper *O Comercial*, the hull was broken up, part inside and part outside the water, and the cargo spread along 6km of beach. All crew and passengers were apparently dead, since a launch had been found with bodies further north, while others corpses washed ashore on the beach near the wreck site.

With the easing of the weather and improving sea conditions, more than 40 vessels were guided in and out the bar during June 14 and 15. A call for public auction was published on June 16 for the salvage rights and the selling of material rescued from the English *patacho Hound*, stranded to the south of the bar on June 7 (*O Comercial*, June 16, 1861):

> Egídio Tallone will sell in public auction to be held in the Boa Vista street, near the pier of the Carmo church, by order of honorable Dr. H. P. Vereker, consul of His Britannic Majesty, the hull of the English patacho Hound, wrecked to the south of the bar, classified as AE1 in the Lloyds, sheathed with metal and fastened with copper, with everything inside, which is stranded in 5 or 6 feet of water, 1 superior oak launch, various yards, topmasts, 1 set of sails, cables, rigging, chains, etc.

Two weeks later, the announcement of public sale of the hull and salvaged parts of the English *barca Prince of Wales* was published in the newspaper (*O Comercial*, June 29, 1861):

> Auction of the hull and belongings salvaged of the British brigue[6] (sic) Prince of Wales wrecked at Estância. Tuesday, July 2nd, at 11am precisely. By J.M. Perry de C. [auctioner] at the Customs doorsteps, and in the presence of honorable Sr. consul of His British Majesty [H. P. Vereker], authorized by the Customs inspector. Hull and rigging as it is in the beach. One launch and 1 jolly-boat. Ten oars, topmasts, yards, studding sail booms and spares, sails, etc. In the same occasion, by the order of the inspector an the Sr. Consul, the following salvaged items from the ship, belonging to his consignee: 262½ dozens of calico handkerchiefs, 22 ditto of black silk, 4 trunks with 940 dozens of white tread reels, in perfect condition, 16 cans of ditto, ditto, ditto, 53 pieces of fringed cotton. Terrines, trays, urinals, jars, etc. One barrel of butter, 1 ditto of radish oil, 2 cans of flaxseed oil, empty bags, etc, etc.

[6] Probably a typo, since the *Prince of Wales* was *barca*, or bark rigged.

Analysis

Apparently during the period involving the loss of the *brigue Guahyba* a cold front passed over the southern Brazilian coast, which intensified in the night of June 1 to 2 with gale force winds from S to SE quadrants, lately turning to SSW (Figure 26).

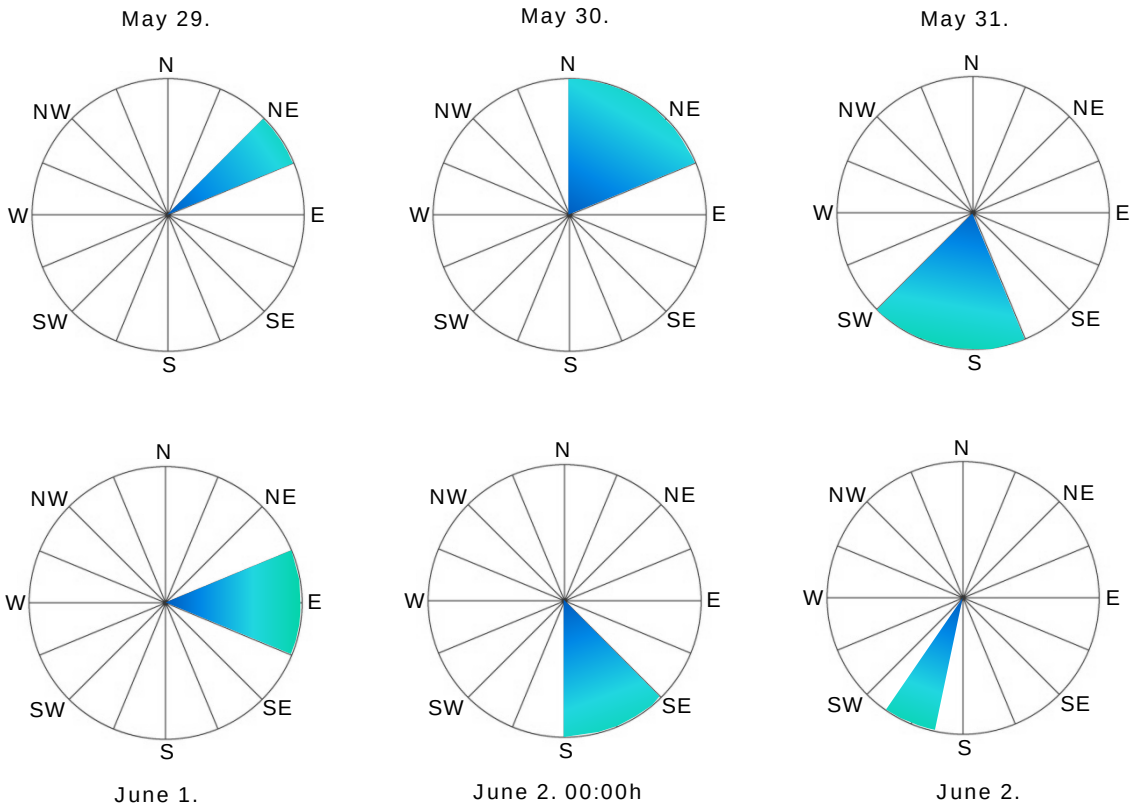


Figure 26. Wind roses with information on prevailing wind directions from May, 29 through June, 2, 1861.

The foggy weather that followed is an indication that the front was blocked on its track and became stationary over the ocean to the northwest, with winds varying from S to WSW quadrants. On the night of June 7 to 8, winds from the S to SE picked up again,

probably as a result of the formation a cyclonic vortex, culminating with the loss of the *Hound*, purposely grounded by its captain, and the stranding of the *Prince of Wales* to the south shore near Albardão beach (Figure 27).

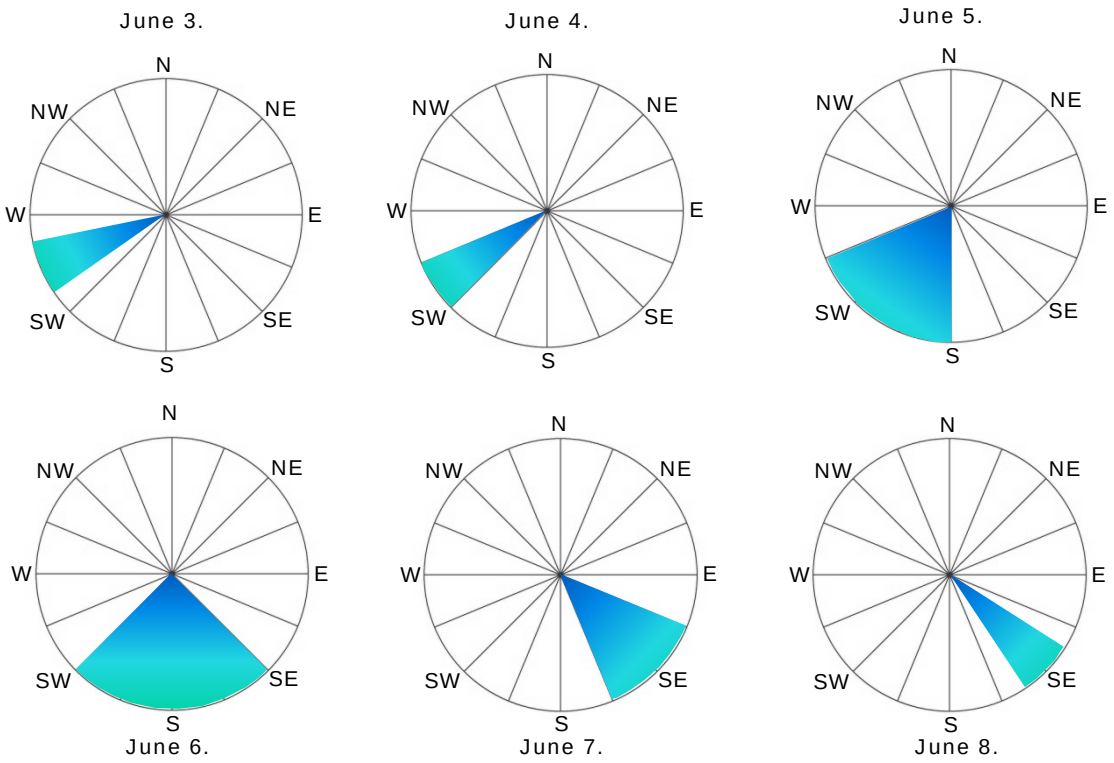


Figure 27. Wind roses with information on prevailing wind directions from June 3 through June 8, 1861.

4.2.2 The Case of Fishing Vessel *Magalhães II* (2003)

In the morning of July 9, 2003, the fishing vessel *Magalhães II* ran aground at Albardão beach, on the south shore of Rio Grande (Figure 28). Manned by a crew of

seven, the ship left the port of Rio Grande on Sunday, July 6, prepared for fishing over the continental shelf in the rich fishing grounds near the border between Brazil and Uruguay. The small wooden trawler was built in 1978, with an overall length of 13.2m and capacity for 20 tons of fish. It was equipped with PX radio, GPS, and echo sounder, which were all working properly at the time of the accident, according to investigations led by the Port Authority of Rio Grande do Sul (Inquérito Naval, Processo Nº. 20.627/03).

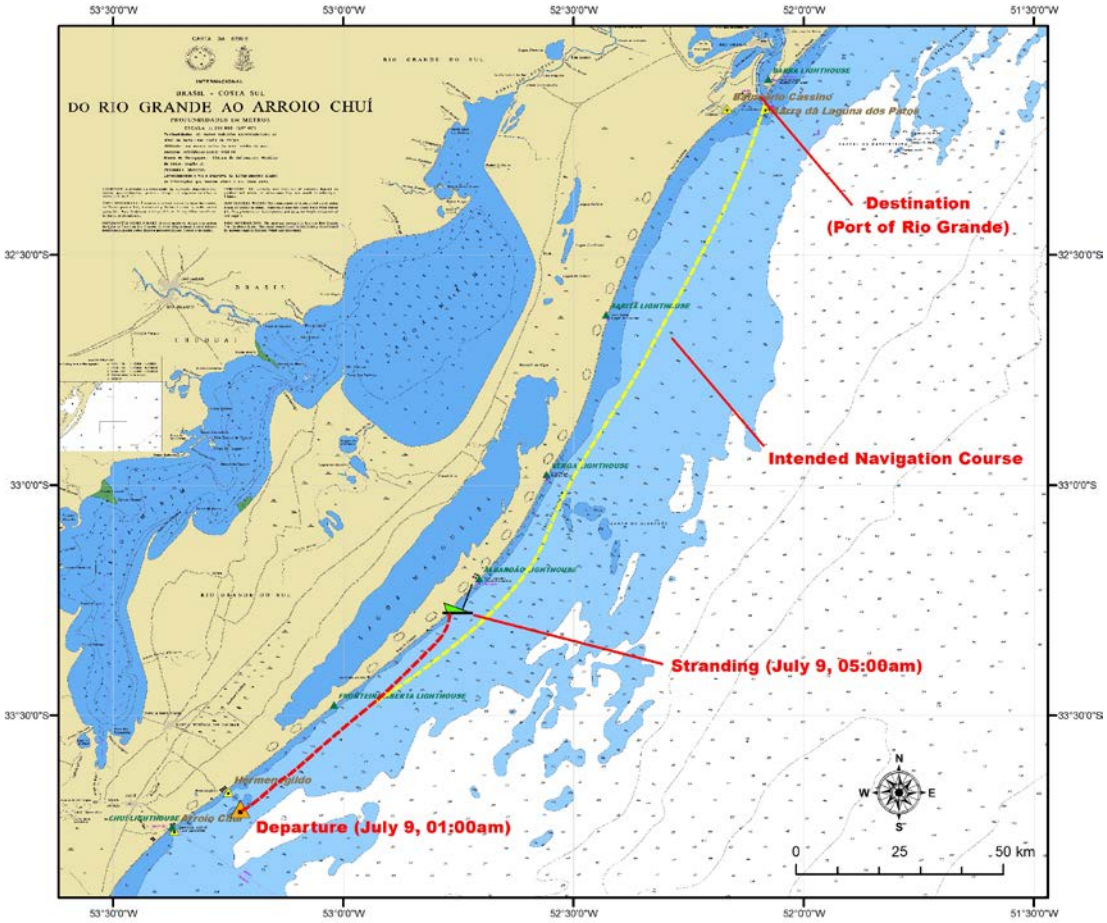


Figure 28. Plotted track of fishing vessel NP *Magalhães II*, showing the stranding location.

On the day before, Tuesday, July 8, the *Magalhães II* had dropped anchor at Hermenegildo shoal, near the border with Uruguay, together with three other vessels, due to strong winds which started to jeopardize navigation and fishing. Around 1am, Captain Luiz Nunes Machado decided to return to the port of Rio Grande located 100 nautical miles to the north, in the face of the approaching storm.

The ship was being conducted by the cook, who was alone at the helm while the others were sleeping, when the accident happened. According to the cook's report to the Port Authorities, he was supposed to keep course by tracking the 20m bathymetric line, using the echo sounder, compass, and GPS readings. He alleged that, at approximately 5am, the readings of the echo sounder started to be erratic, and all of sudden the ship was in 10 meters of water, at a speed of 7 knots, bearing 300º. Beaten by 2m to 3m high waves, according to his observations, the ship got helplessly adrift across the breakers piling onto the beach.

The ship's keel first hit the sand bank in the trough of a wave, damaging the propeller shaft and allowing water to leak into the hull, thus forcing the crew decide to abandon the ship (Figures 29). Without knowing for certain where they were, the fishermen only had time to gather a few belongings and a match box wrapped in a plastic bag before jumping into the cold water, tied to each other by a salvaged rope.

Upon reaching the beach, they looked for shelter in between the dunes, where they managed to light a bonfire to warm up and dry out their clothes. In the morning, a crew member went to search for help at the *Albardão* Lighthouse, 10 kilometers north from where the accident happened. Five hours later, they were rescued by a helicopter of

the Brazilian Navy. Less than a week later, once the sea had receded past the storm surge, the old ship was found totally lost, broken up into pieces spread along the beach (Figure 30).

Figure 29. Situation of the vessel a few hours after the accident (Photo: Flávio Neves).

Figure 30. Broken up remains of the fishing vessel *Magalhães II* portside bow, as seen less than a week after the accident (Photo: Flávio Neves).

Analysis

The weather configuration on July 8 at 09:00am (20 hours before the accident) indicated the incipient development of an extratropical cyclone (LP: 1002mbar) centered at approximate coordinates 36ºS/40ºW, formed at the tail of a cold front developed in the contact between a migratory anticyclone (HP: 1016mbar), centered at 33ºS/47ºW, and the South Atlantic anticyclone (HP: 1028mbar) centered at 30ºS/15ºW (Figure 31).

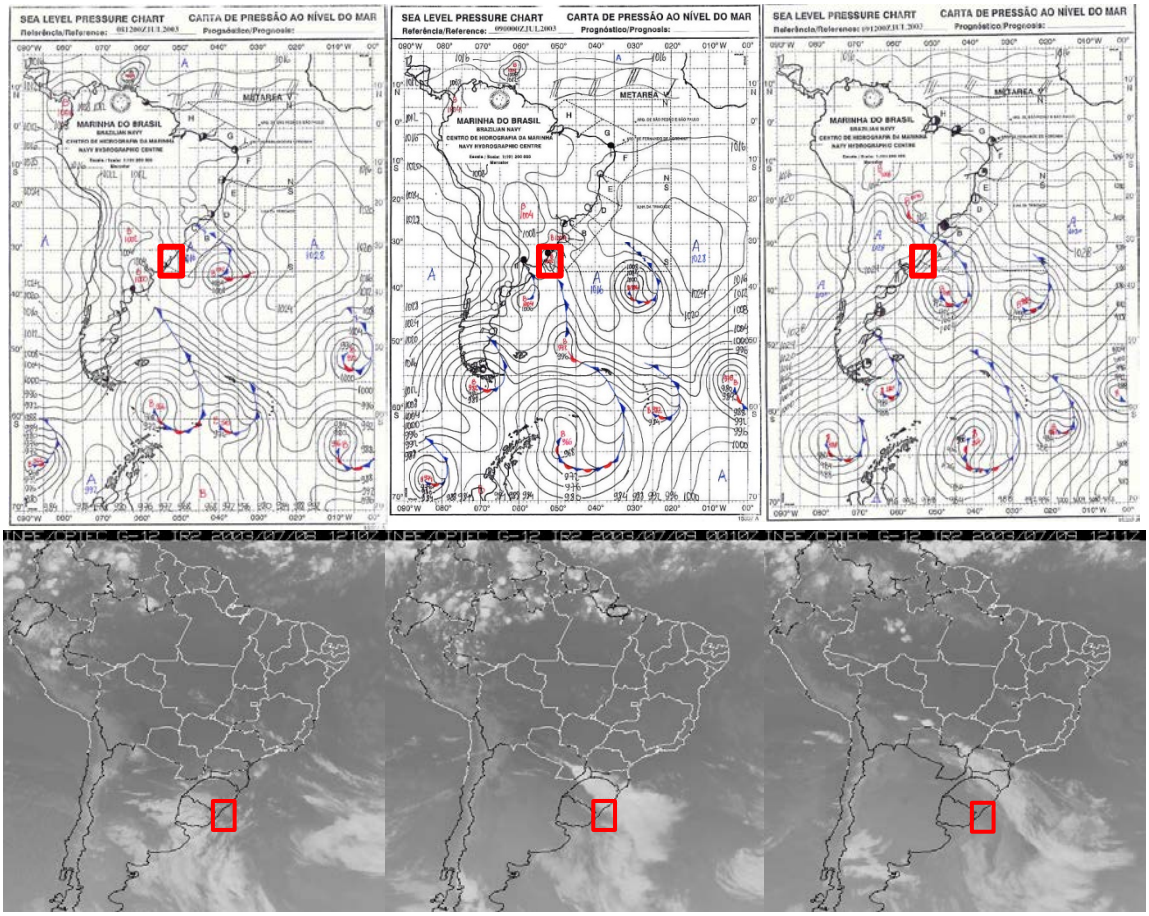
Eight hours before the accident (July 8, 09:00pm), the extratopical cyclone intensified (LP: 996mbar, center at 40ºS/30ºW) as it moved away from the coast. Another low pressure zone then started to form across the north coast of Argentina,

Uruguay and southern Brazil (centers at 43ºS/58ºW, 33ºS/52ºW, and 28ºS/50ºW). The satellite image shows a well-developed cloud band in 'inverted coma' shape, spreading NW-SE for approximately 2,000km, part over the continent, part over the ocean, indicating the passage of another cold front over the study area in a period of approximately 48 hours.

Results from the numeric model RAMS (Regional Atmospheric Modeling System[7]) showed the formation of a wind field oriented SW-NE off the coast below the River Plate and extending to the Uruguayan coast on July 8 at 9pm, reaching 55 to 65 k/m[8] (Figure 32). Six hours later, the wind field was reaching the Brazilian coast with 45 to 55km/h SW winds. Between 3:00am and 6:00am, July 9, hence encompassing the period when the accident happened, the model predicted an intensification of the wind field. The core of highest speeds was then off the Rio Grande do Sul south shore, blowing at 65 to 70km/h.

[7] The model outputs were produced by the team researchers from the Meteorological Laboratory GERPA at Federal University of Rio Grande. Numeric models are used to simulate and forecast meteorological events, in this case, based on the integration of differential equations of conservation of mass, energy and movement, with reference to a coordinate system.

[8] 1km/h equals 0.54 knots or nautical miles per hour.



July 8, 09:00am July 8, 09:00pm July 9, 09:00am

Figure 31. The development of the weather system. Above, synoptic charts produced by the Brazilian Navy Hydrographic Office. Bellow, satellite images GOES-8 Infrared. The accident location is marked with a red square.

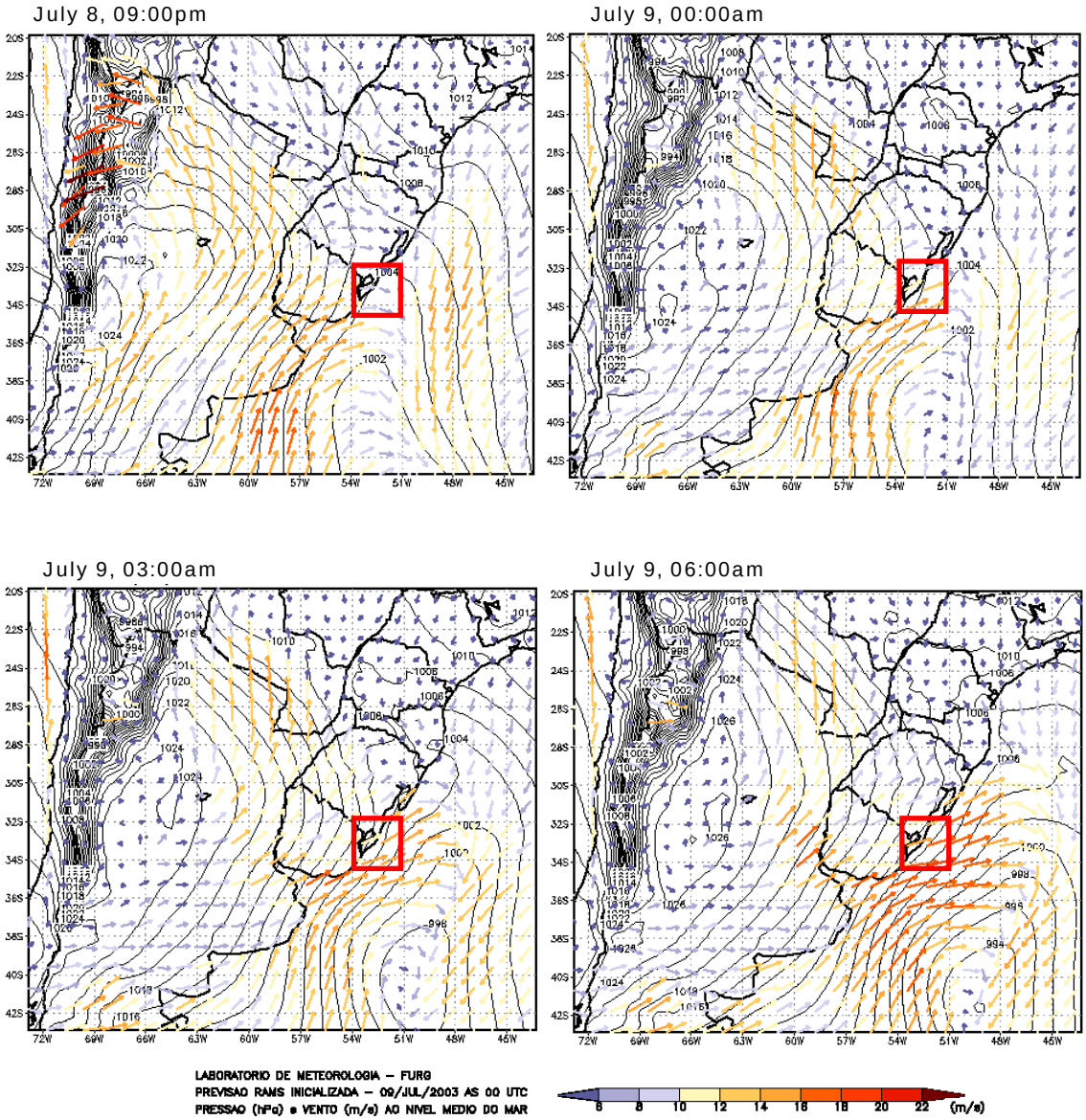


Figure 32: Atmospheric numeric model outputs showing the development of the wind field during the accident.

4.3 Shipwrecks and the Beach Environment

In the course of this research several field trips have been carried out to record and monitor shipwreck sites along the southern and central shores in the study area. Twenty one sites showing evidence of stranded ships have been entered in the GIS database (Figure 33).

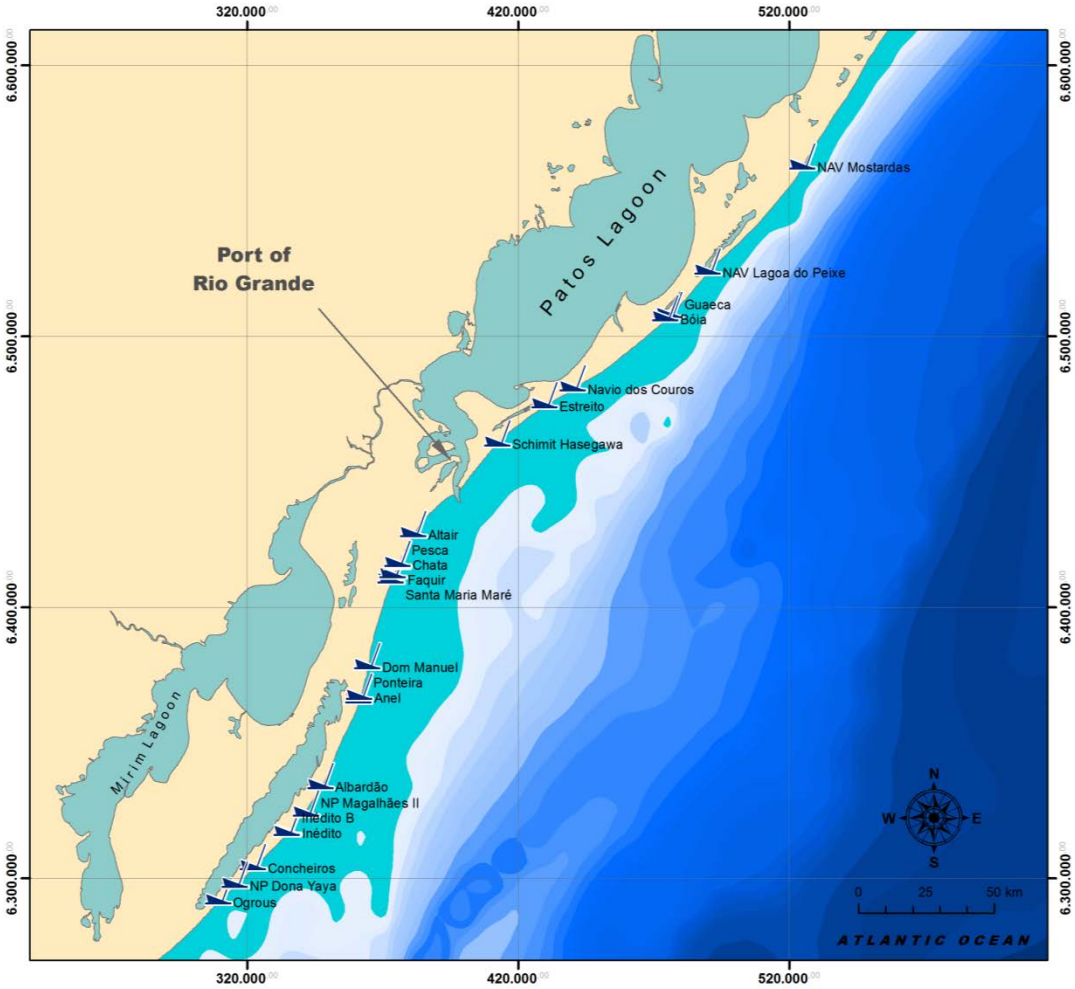


Figure 33. Map showing the position of shipwreck sites located during field research.

Ships from different periods, construction materials and degrees of preservation have been found along the beach, partially buried in the sand, in the surf, swash zone or high up near the dune field above the high mean water mark (see Appendix B for reference). Below, an idealized cross-sectional beach profile presents the nomenclature used to identify the various divisions in the coastal zone (Figure 34).

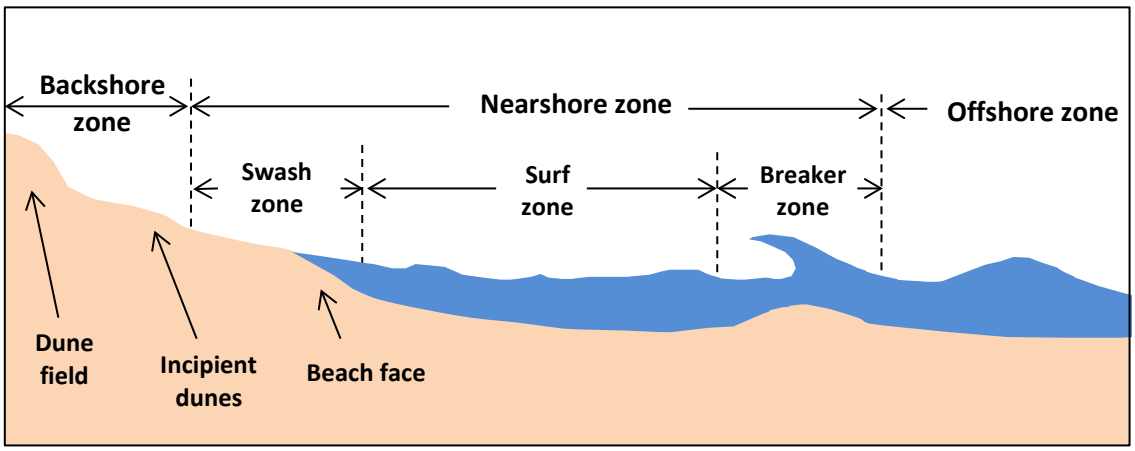


Figure 34. Idealized beach profile (not to scale).

It is understood that the formation and survival of the archaeological record will ultimately depend on, first, the probability of occurrence of accidents; second, the characteristics of the ship and the circumstances of the accident; and third, its interaction with natural and cultural post-depositional processes. The discussion in the following section approaches those aspects of the formation processes related to the interaction between shipwrecks and the beach environment in the study area.

Beach environments are among the most energetic and complex depositional systems in the world's oceans (King, 1972). Winds, waves, storm surges, coastal currents, and consequent sediment transportation are the main elements affecting the archaeological record in the studied sites. Interaction between these elements occurs continuously across space and over time, and within various significant spatial-temporal scales, resulting in natural cycles of flood, burial and exposure of stranded wrecks.

Wind fields generated from weather systems off shore act upon the sea surface creating waves, which eventually break upon shore, originating currents, and providing most of the energy responsible for shaping beach deposits. However, due to changes in coastline orientation and inner shelf gradient, beaches along the shoreline will present differences in the degree of exposure to prevailing hydrodynamic factors. Therefore, actual environment response will depend on the nature and level of energy inputs, and the physical characteristics of the coastal zone (Short & Hesp, 1982).

As seen above, costal processes in the study area are closely related to seasonality of weather patterns. During summer months, when the weather is generally calmer, waves approach in more regular swells, carrying in and accumulating sand right above the swash zone, thus resulting in a beach profile which is more concave upwards with a broad berm and steeper beach face (Figure 35).

During winter and mid-seasons, high energy events such as the already-mentioned cold fronts, extra-tropical cyclones and storm surges are more likely, and steep waves mobilize great amounts of sediments in short-term episodic events as it reaches the shore. The typical profile response is to reclaim sand deposited on the

backshore under previously calmer conditions, carrying it away seaward, where it will be reworked by waves and coastal currents into characteristic longshore bars.

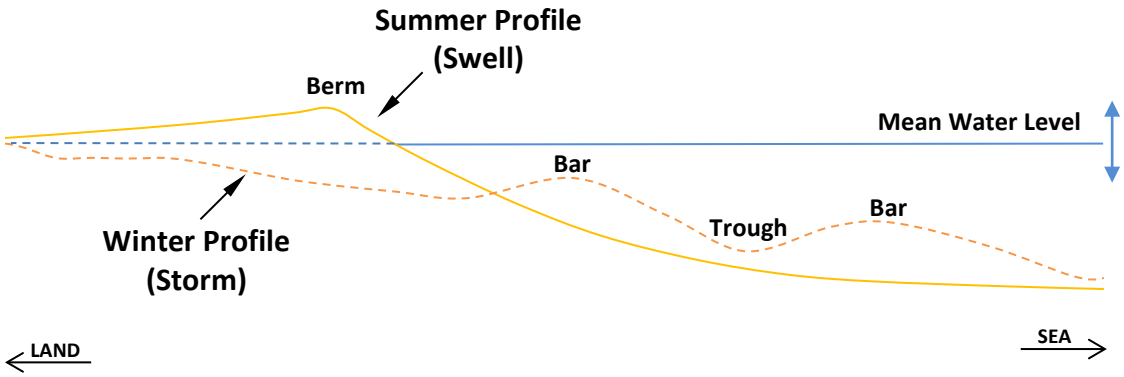


Figure 35. Generalized variations in beach profiles in response to changing energy conditions (Modified from Komar, 1983: 7). Not to scale.

The maximum horizontal and vertical reaches of these disturbances, both seaward and landward, define what is called the active zone of the beach profile. Therefore, shipwrecks and beach deposits in this active zone will then be constantly reworked by breaking waves, coastal currents and eolian processes, until long-term changes in environmental conditions come to alter the relative position of the active zone.

In this regard, a useful theoretical concept applied to study sedimentary processes in sand barriers is the idea of sediment budget. It is basically an application of the principle of conservation of mass to the littoral sediments and, in practice, consists of estimates of the principal sources of sediment input (credits) and sediment losses (debits) for a stretch of shoreline (Komar, 1983: 18). The resulting balance is an indication of the

net state of the studied unity, reflected in areas of local beach erosion, accretion or stability (steady-state).

Within historical periods of time, a coastline is said to be *prograding*, when long-term positive sediment balance results in net sediment accumulation and seaward beach growth, whereas it is said to be *retrograding*, when persistent sediment deficits result in a landward retraction of the barrier. Figure 36 presents a map with data for shoreline orientation calculated every 10km along the coast and the zones in the RSS where long term negative sediment budgets have produced erosional patterns. Red rectangles mark the areas with greater exposure to more energetic wind and waves from the southern quadrants. Red dots mark erosional areas, whereas yellow dots mark stable areas.

Note that the erosional zones coincide with the stretches of coast that are more exposed to highly energetic winds and waves from the southern quadrants (SW, S, and SE). Clearly, an understanding of the regional factors controlling spatial-temporal positioning of the active zone of beach profiles along the barrier is of fundamental importance to the study of beach stranded shipwrecks.

In the following sub-section a preliminary report of the excavation carried out in 2013 at the site NAV Lagoa do Peixe is presented. The main findings will be analyzed as a baseline for discussions presented in the following sections.

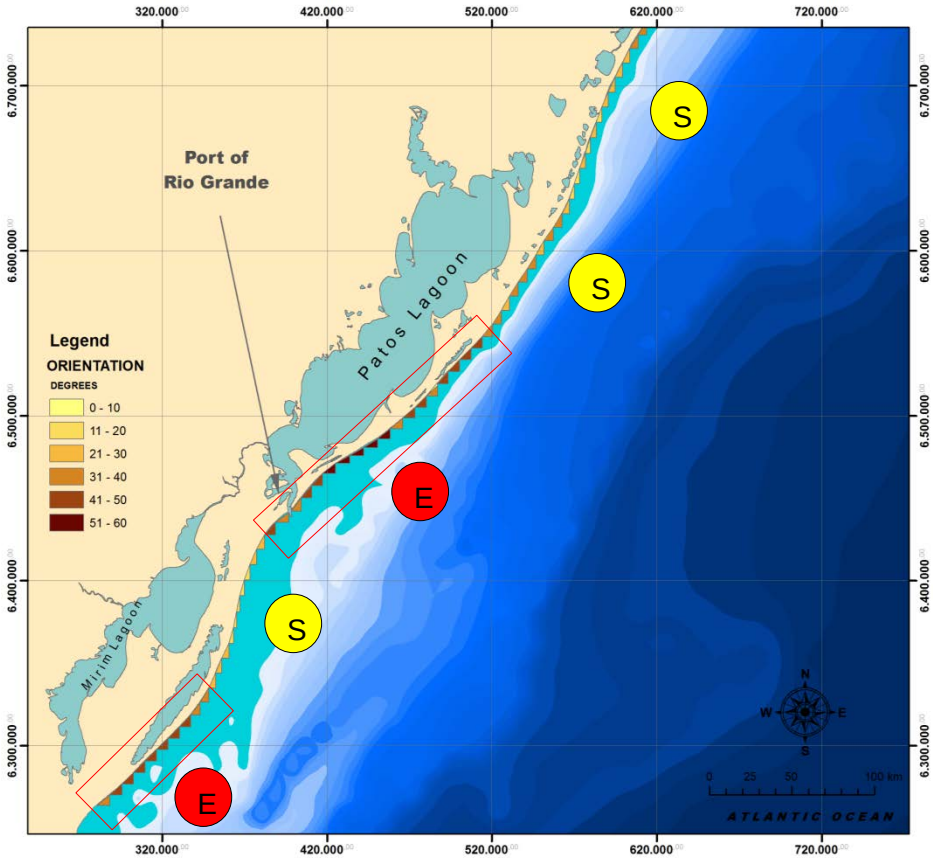


Figure 36. Map with variations in shoreline orientation and erosion data. Red rectangles mark the areas with greater exposure to more energetic wind and waves from the southern quadrants. Red dots mark erosional areas, whereas yellow dots mark stable areas. Beach erosion data from Calliari et al. (2006).

4.3.1 NAV Lagoa do Peixe Site

This site is located at the northern portion of the central shore, 10km south of the Lagoa do Peixe inlet, at coordinates UTM 22S 488,902.991E 6,523,927.195N. It is composed of four disarticulated wooden structures (1,2 3 and 4) found partially buried in the sand and spread over an area of approximately 1,200m^2, as seen in the sketch below, drawn in 2002 (Figure 37).

In 2011, two topography benchmarks were deployed and five control points were established on each of the four visible structures. The control points were surveyed using a total-station (Leica® TPS400), and cross-shore survey profiles were taken (Figure 38). During a 10-day fieldwork campaign in 2013, Structure 1 was excavated and recorded in detail, Structures 3 and 4 were partially excavated, also recorded with photos and photogrammetry, while Structure 2 was only recorded with photos and photogrammetry. The recording methodology encompassed the following steps:

a) Pre-disturbance survey using photogrammetry and detail photography;

b) Definition of the excavation area and recording of control points;

c) Hull cleaning using trowels, brushes and spatulas;

d) Photo coverage for photogrammetric processing every other day;

e) Detail recording of hull features;

f) Survey of artifact distribution;

g) Covering the site with its own sediment.

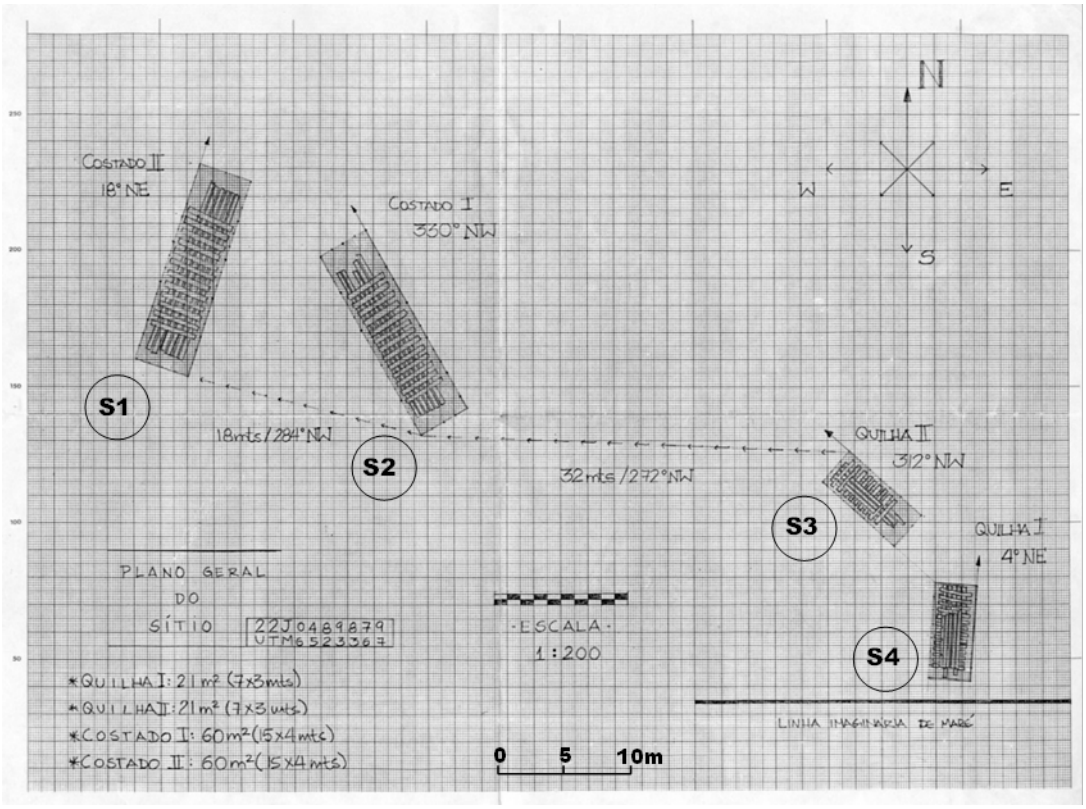


Figure 37. Site plan for NAV Lagoa do Peixe shipwreck done in 2002, showing relative position of the recorded structures.

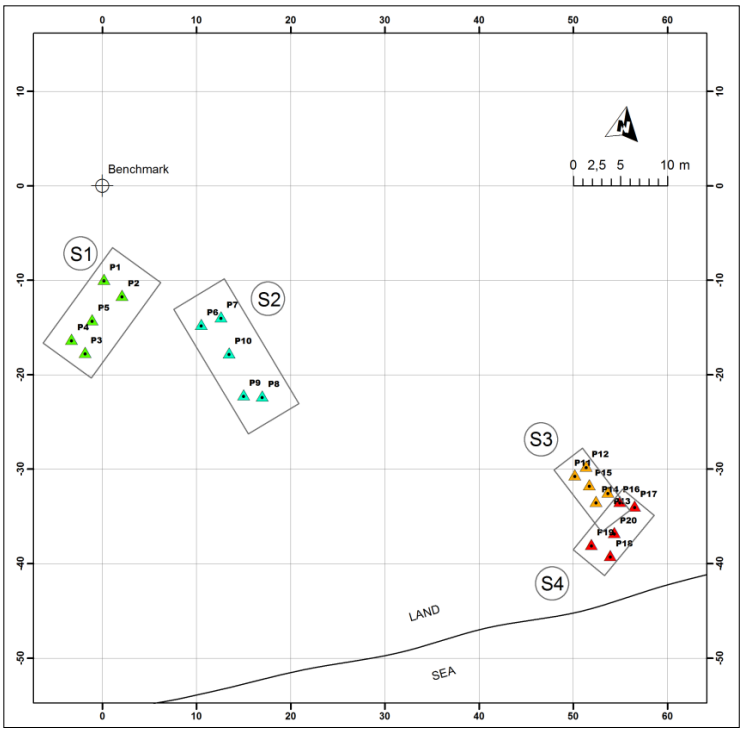


Figure 38: Installation of benchmarks, control points and profile survey done in 2011.

In this work photogrammetry was used to build 1:1 three-dimensional (3D) models of structures excavated, allowing for precise measurements and the study of spatial relations among the registered features. The software used for photogrammetric modeling was PhotoScan Agisoft© Professional version 1.0.4, architecture 1847 (Agisoft, 2014). Photographs were taken at oblique angles with a DSLR Nikon© D7100 camera, with a 24 megapixel sensor and saved in JPEG format. Following the software requirements, pictures were obtained with 60% to 80% overlap, ensuring that each point and feature in the structure to model appeared in at least two photos (Figure 39).

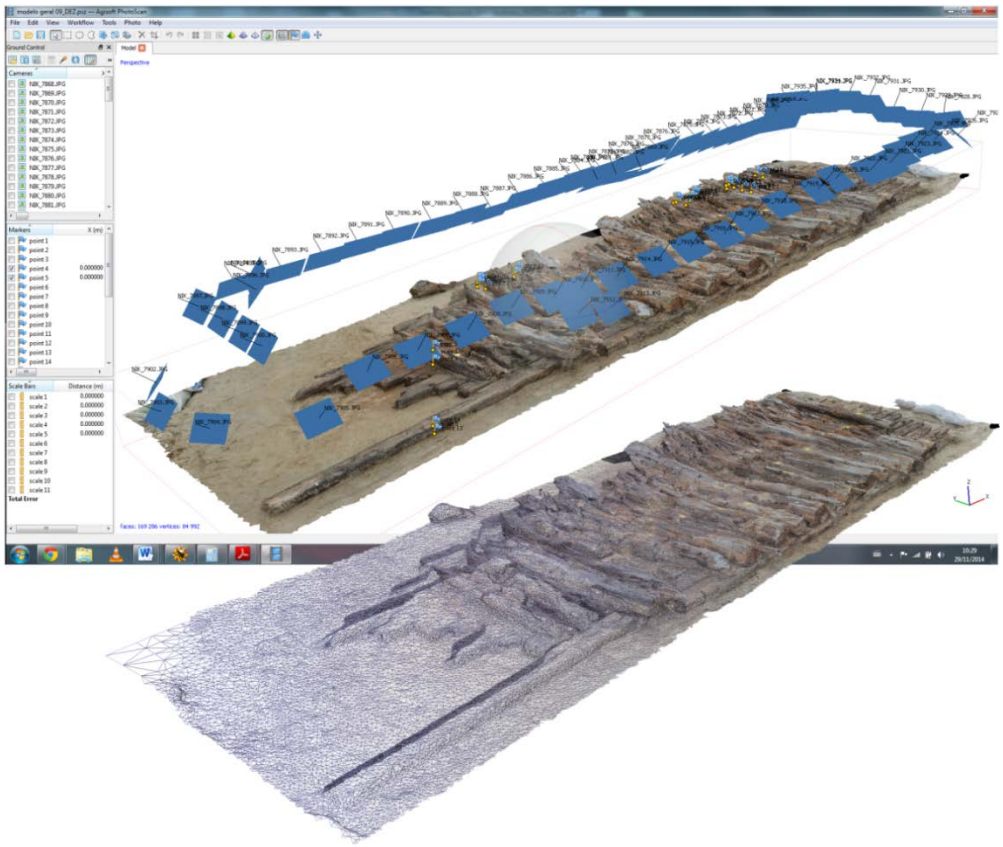


Figure 39. Above, print-screen with software interface showing camera positions (blue squares) for generation of Structure 1 model. Below, a blend of wireframe and textured 3D models.

The models were processed by the software in the basis of geometric relations obtained from the set of photos. A comparison of several measurements calculated within the photogrammetric models with measurements taken in situ using the Total Station indicates accuracy for the 3D model in the order of 0.002 to 0.003m in 10m (~0.03%).

After a pre-disturbance survey, the sterile unconsolidated sediment layers around the excavated structures were removed carefully with the aid of hoes and shovels, while trowels, brushes and wooden spatulas were used to remove sediment in between the

ship's timbers (Figure 40). The sediment removed from the excavation was sieved using a 0.005m mesh, and used for filling sandbags used to stabilize the excavation flanks. Tarps were used to cover the parts exposed by excavation, avoiding excessive sun exposure and reburial by the constant wind-blown sand (Figure 41).

Figure 40. Excavation conditions at the site NAV Lagoa do Peixe.

As a section of the hull was being exposed, the excavation progress was registered in photos and videos, and controlled through daily photogrammetric coverage, drawings and total station surveys. The 3D models were then scaled and referenced to coordinates of the established control points. PhotoScan© software also allowed

exporting projected ortho-corrected images (orthophotos) from the model, to be saved in GeoTIFF.[9]

These orthophotos were imported as base maps into ESRI ArcGIS© software version 10.2, enabling partial site plans to be delivered at scale 1:10, so that archaeologists could use them for detailing structures and features in situ, thus optimizing greatly the recording effort (Figure 42). After the structures were properly recorded, the site was covered with the same sediment removed from the excavation, restoring the original landscape.

An extensive area surrounding the exposed structures was surveyed in search of potential artifacts and dismembered hull features. A handheld metal detector was used following 4m spaced transects, and opportunistic visual inspections were performed on areas naturally exposed by the shifting sand in the dune field. The findings were plotted with a hand-held GPS Garmin© EtreX, photographed and drawn, when appropriate (Figure 43).

[9] GeoTIFF is a public domain metadata standard which allows georeferencing information to be embedded within a TIFF file.

Figure 41. Above, protection against shifting sand. Below, situation of Structure 1 once completely excavated.

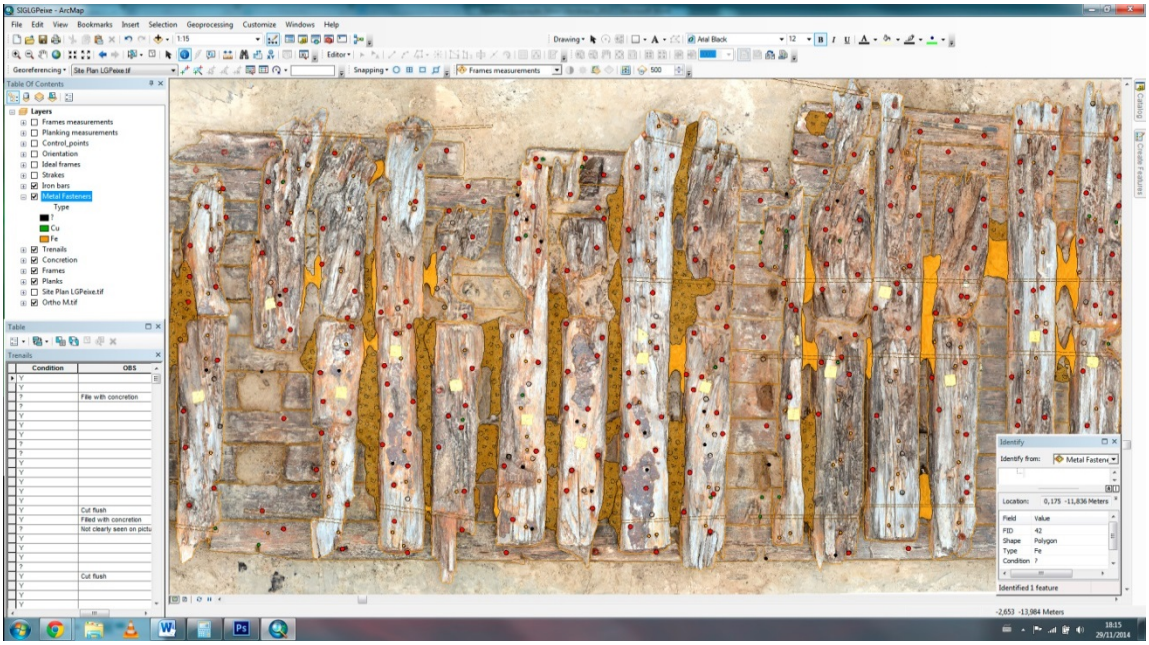


Figure 42. Print-screen of ArcGIS interface, used together with photogrammetry to manage excavation documentation.

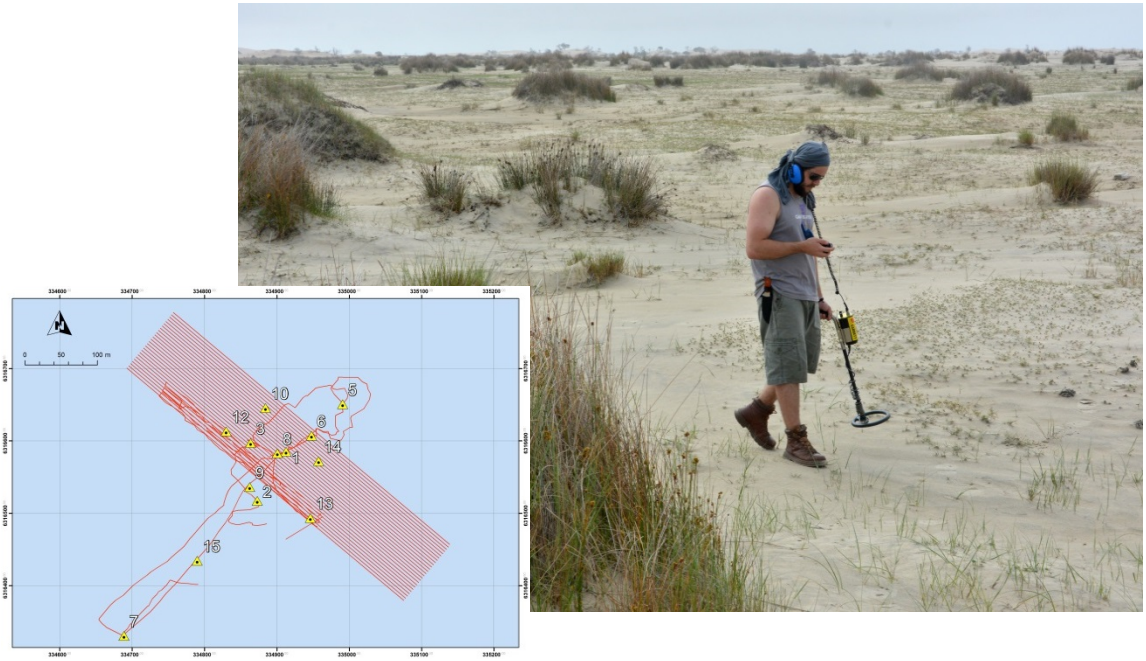


Figure 43. Map showing plotted pre-planned transects and opportunistic visual survey tracks, with findings marked in yellow.

The excavation of Structure 1 revealed the remains of a wooden ship's lower hull, comprising of 21 articulated frame timbers and 14 strakes of outer planking, extending over an area measuring 12.7 x 3.4m (Figure 44). Timber measurements were taken where surfaces were better preserved and are shown in Figure 45. Each frame was composed of alternating timbers, fastened two and two by means of longitudinal iron fasteners called frame bolts (Ø 0.02m). Room and space averaged 0.42m on centers, with the space between each set of frames ranging from 0.10 to 0.15m. Frame bevels were recorded on four frame timbers: F11, F15, F17 and F18, varying between 9 to 11°.

Planks were double-fastened to each frame with round treenails (0.40m long, Ø 0.03m) wedged from the outside only, and trimmed flush with the frames inner surfaces (Figure 46). Plank ends were butt-joined, each secured by three copper alloy blunt bolts[10] (0.30m long, Ø 0.025m) (Figure 47). The molded plank molded dimensions were quite consistent around 0.11m, while measured sided dimensions varied substantially, ranging from 0.20m (S14) to 0.25m (S2).

No other distinguishable timbers, such as ceiling, wales, stringers, shelf planks, keel or keelson were preserved in Structure 1. However, the remains of Ø 0.02m iron bolts protruding above the fames inner surface suggests the existence of internal planking. Deterioration of the frames surfaces and concretions prevented the recognition of patterns (Figures 48 and 49).

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[10] *Blunt bolt* refers to a type of bolt made out of cylindrical rods (iron, copper or composite), headed or not, having a slight chamfer on the entering end, intended to stop short of full penetration of the timbers, as opposed to *through bolts* (Crothers, 1997: 68-69).

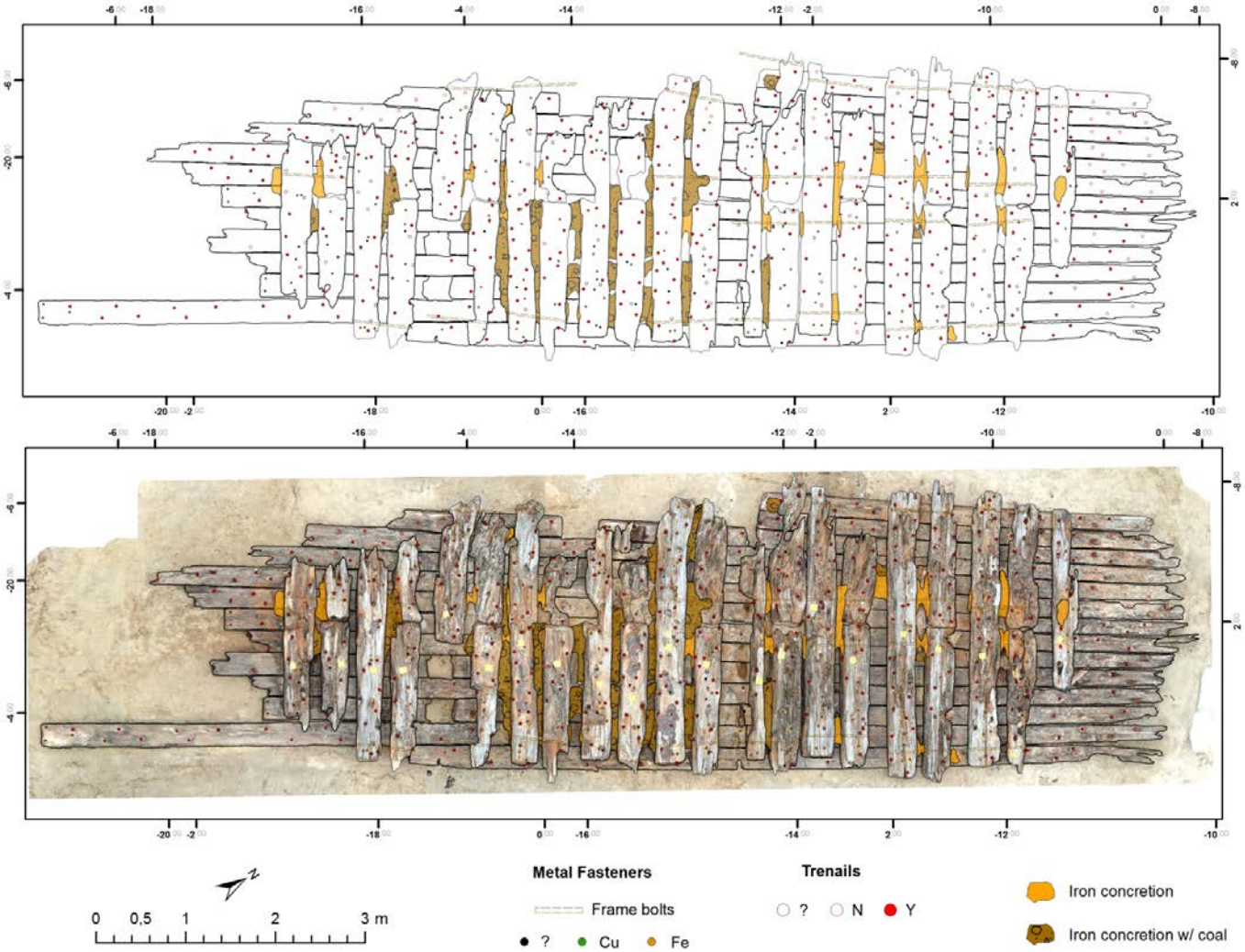


Figure 44. Structure 1. Left, outlined plan of frames and planking, treenails, metal fasteners and concretions. Right, same plan but backed by an orthophoto.

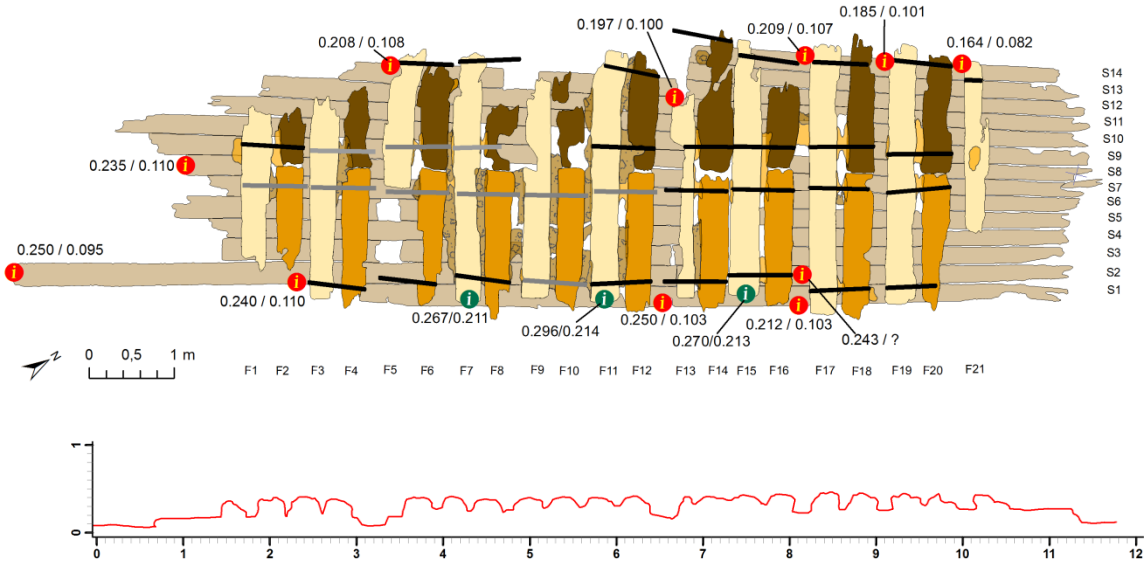


Figure 45. Outline of Structure 1 showing scantling measurements on preserved surfaces of frames (green) and planks (red), first number for sided dimension, second for molded dimension, in meters. The position of observed longitudinal iron bars are in bold black, and other positions suggested by concretions are in gray (thickness exaggerated for visualization). Below, a longitudinal profile.

Figure 46. Treenail piece from strake 7, showing wedged end.

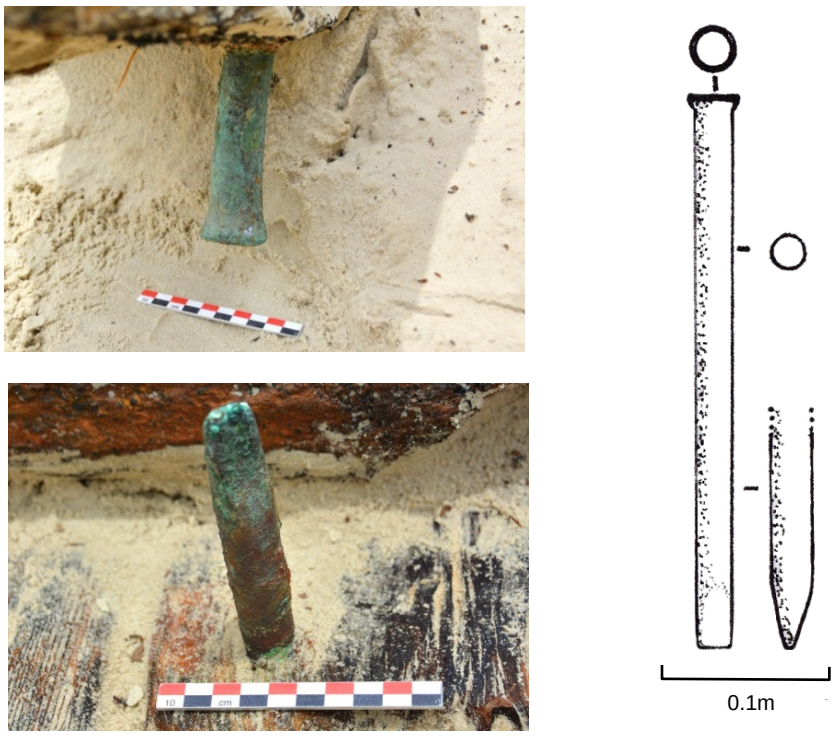


Figure 47. Details of copper alloy blunt bolts used for fastening the planks ends.

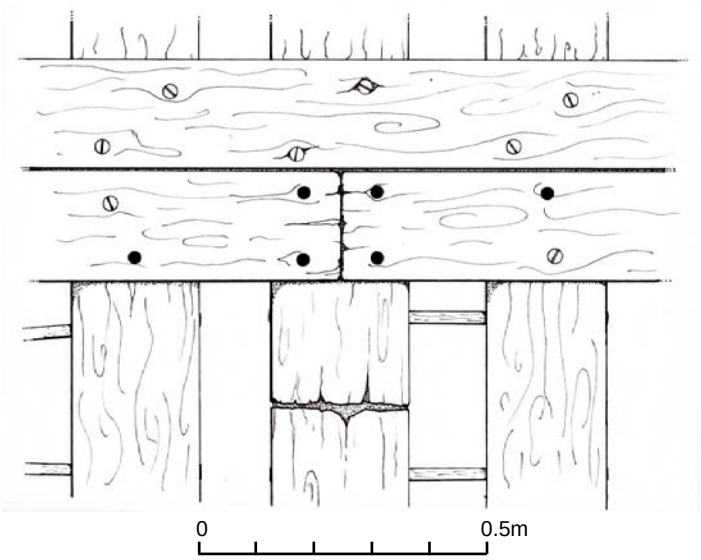


Figure 48. Idealized planking and frames seen from outside the hull, showing copper alloy blunt bolts in solid black, wedged treenails and longitudinal frame bolts.

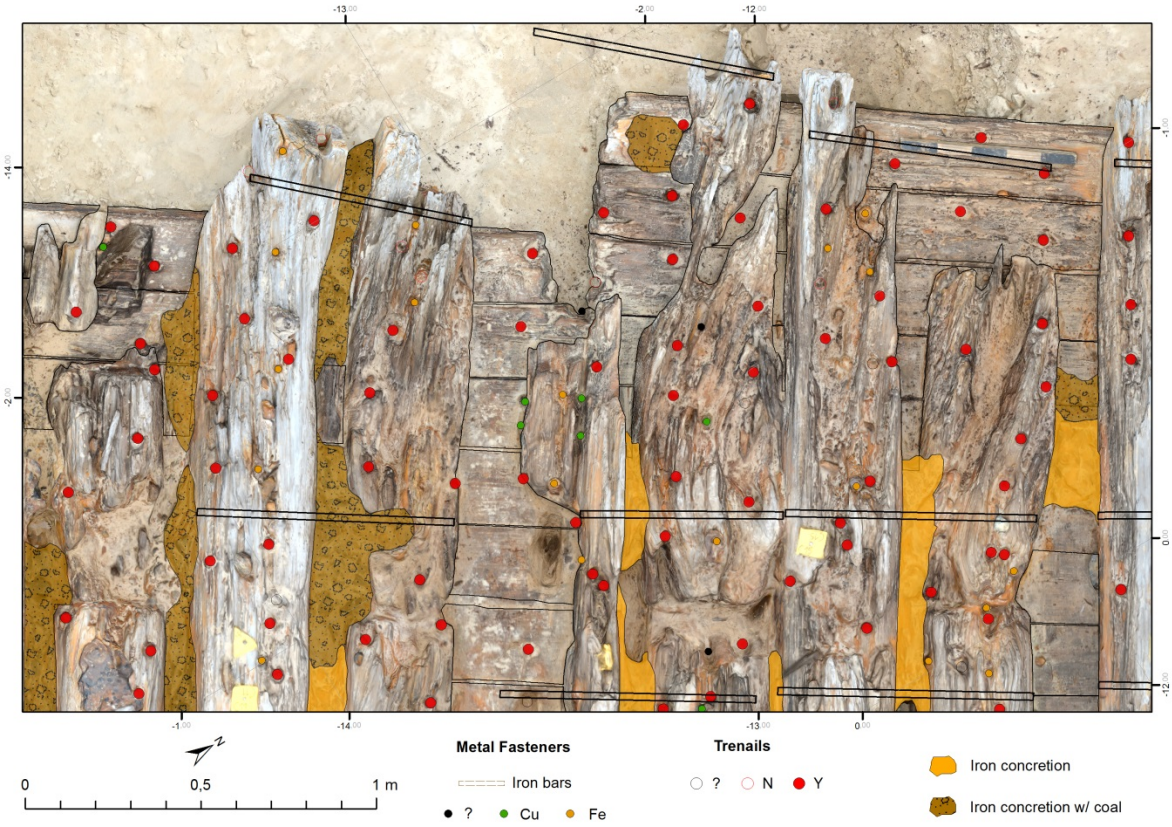


Figure 49. Distribution of fasteners.

Metal sheathing was identified at two points on the outside of outer planking in Structure 1, confirming it to be part of the ship's lower hull. Although no analysis of the sheathing was made at this time, a characteristic green patina suggests that it is composed of copper alloy (Figure 50). Another diagnostic feature present in this shipwreck is the abundant occurrence of coal in between the frames, adhered to ferrous concretions, or dispersed around the site (Figure 51). Since there are no natural coal-beds in the area, and no evidence of burnt coal was found, it is suggested to be part of the ship's cargo.

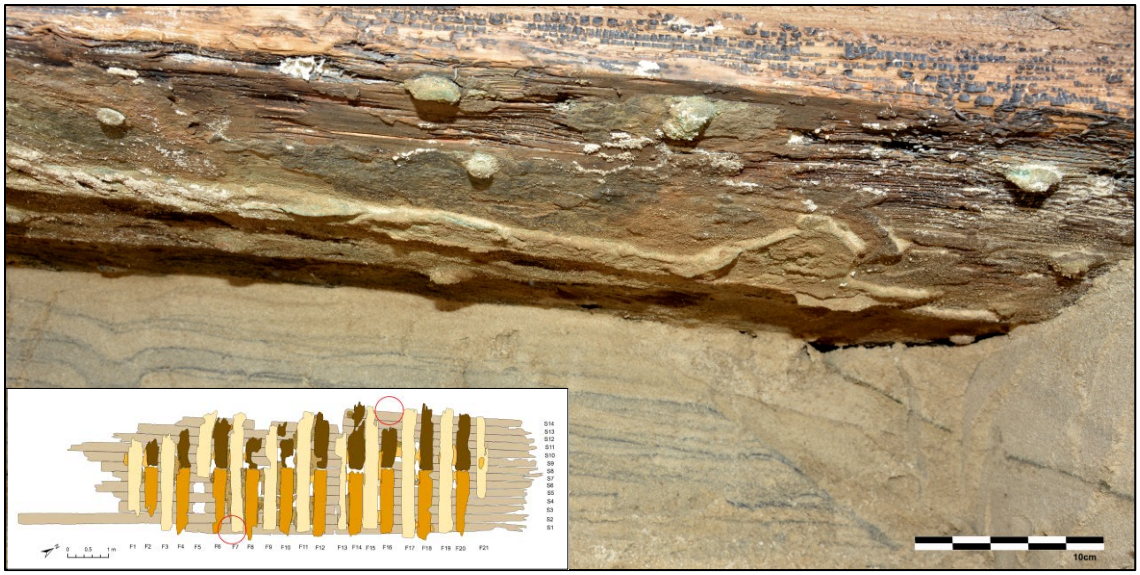


Figure 50. Evidence of metal sheathing on the underside of strake 14, in between frames 16 and 17. In the detail, the two points where metal sheathing was observed are marked with red circles.

Figure 51. Evidence of coal as part of the ship's cargo adhered to a concretion on frame F11.

Apart from coal, the only artifact found in situ which could be associated with the wreck was a cast brass knob or handle, conserved and analyzed at the facilities of the Conservation Research Laboratory at Texas A&M University (Figures 52 and 53). X-Ray Fluorescence analysis on a small sample of metal shavings taken from the knob's shaft after conservation resulted in a predominant composition of copper (64.5%) and zinc (28.2%), with 7.3% of other elements, including 2.0% rhodium, 1.4% lead, 1.15% nickel and 0.01% tin. Preliminary research suggests it could have been used as a crank handle of some sort, such as the ones commonly used for grinders of the period, or as furniture knobs from the ship's interior fittings (Priess, 2000: 46).

Figure 52. Brass knob as found after excavation in between frames 2 and 3.

Figure 53. Brass knob before and after conservation (Photo: Samila Ferreira).

Observations in Structure 2 (see Figure 37) showed it to be analogous to Structure 1, with no major diagnostic features or timbers to be identified, and therefore no excavations were carried out at this time. In turn, structures 3 and 4 were found further down the beach, in the swash zone, approximately 30m from Structures 1 and 2 (Figure 54).

Structure 3 revealed 10 frame timbers, five outer planks and four stringers, extending approximately 6.4 x 2.5m, while Structure 4 consisted of 18 frame timbers, six planks, and also four stringers, extending 10.0 x 2.8m (Figure 55). Scantlings in both structures were consistent with those observed in Structure 1: approximately 0.29m sided X 0.22m molded for the frames, and outer planking 0.09m X 0.21m, measured where preserved surfaces allowed for reliable measurements. Frame spacing (room and space) in both structures averaged 0.38m on centers, with 0.10m in between each pair of timbers. The stringers were found to have a nearly square cross section, measuring 0.19m sided by 0.17m molded dimensions, on average.

Figure 54. Situation of Structures 3 and 4 during a storm surge which reached the area during fieldwork in 2013.

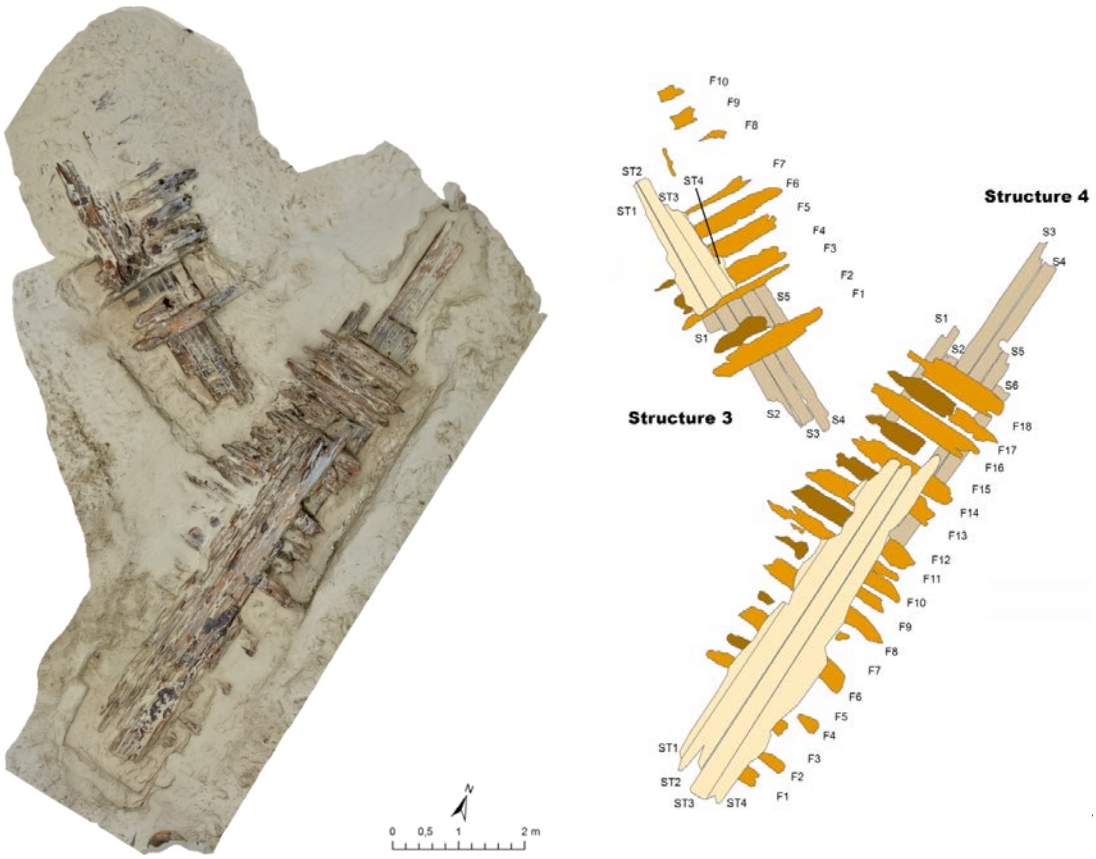


Figure 55. Orthophoto (left) and tagged outline (right) showing relative positon of Structures 3 and 4, as found during excavations in 2013.

These stringers were placed on top of the frames butt joints, right where a sharp change in the frame curvature starts. This feature suggests that the area preserved could correspond to the turn of the bilge, in which case, the preserved stringers should be called bilge stringers (Figure 56). Moreover, after careful consideration, a proposed connection between structures 3 and 4 is presented in Figure 57.

Figure 56. Structure 4 showing the position of planking, frames, bilge stringers and frames curvatures.

According to the database, 12 ships were lost in the area corresponding to the location of the NAV Lagoa do Peixe shipwreck site (Table 1). Out of these, the main cargo was mentioned in eight instances, of which two were of coal, the English *patacho Edine* (1856) and the Prussian *escuna Ejolus* (1868). Although coal has been recorded in shipwrecks as early as 1619 (Bojakowski & Bojakowski, 2011), it became ubiquitous in the 19th century due to its use as fuel for steam machinery and in the process of smelting iron (Björling, 1903: 2-4).

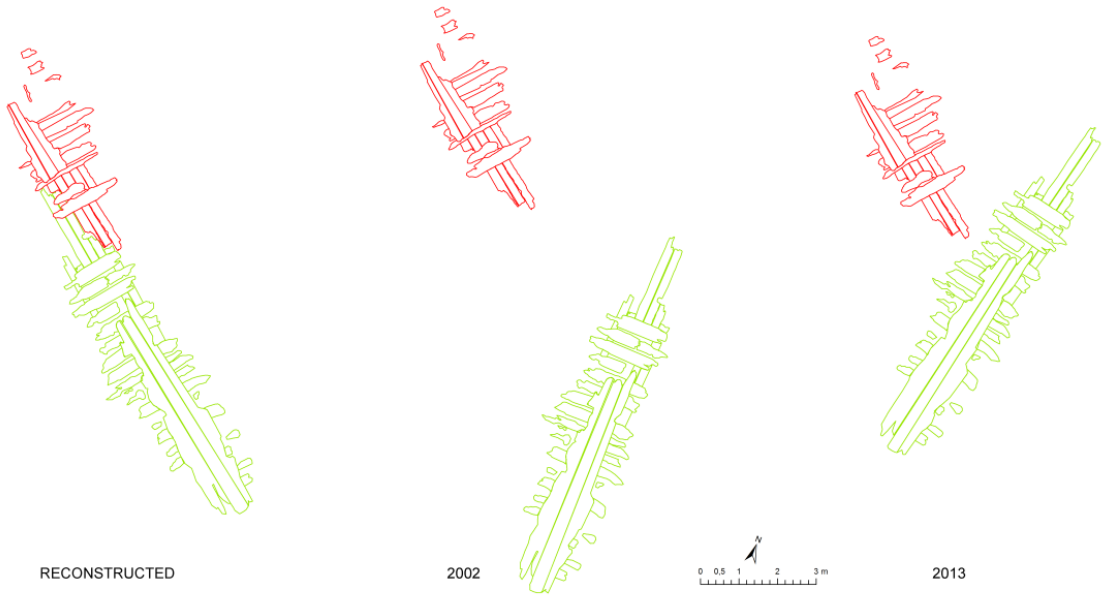


Figure 57. To the left, proposed connection of Structures 3 and 4. To the right, relative positions as surveyed in 2002 and 2013.

DATE	NAME	TYPE	NACIONALITY	MAIN CARGO
1856	*Ada*	*Brigue*	England	Cloth
1856	*Edine*	*Patacho*	England	Coal
1861	*Guahyba*	*Brigue*	Brazil	Assorted cargo
1868	*Alfredo*	*Brigue*	Brazil	?
1868	*Ejolus*	*Escuna*	Prussia	Coal
1874	*Marie*	?	France	Wine
1880	*Lagos*	*Patacho*	Norway	Tallow and Grease
1883	*George Lead*	*Escuna*	England	Wire and Caustic Soda
1884	*Voluntário da Pátria*	Hiate	Brazil	?
1884	*D. Francisca*	*Patacho*	Brazil	Sugar
1885	*Maggie Phillipe*	*Lugar*	England	Bone Ash
1887	*Cavour*	Vapor	England	?

Table 1. Summarized database records of ships sunk in the 19th century near the area corresponding to the location of NAV Lagoa do Peixe site.

Shipbuilding features also corroborate this approximate dating. Copper sheathing for shipbuilding was first introduced in the 18th century, being employed by the British Royal Navy in 1761 as a protection to vessel's hull bottoms against the attack of wood boring marine organisms. However, it initially caused several problems due to yet poorly understood electrolytic reactions in association with iron fasteners that connected the planks to the frames, which was eventually overcome with the replacement of iron fasteners by copper bolts and treenails bellow the waterline (Bingeman et al., 2000: 220).

From 1780 to the 1830s copper sheathing became more common, particularly for naval vessels and larger merchantmen, but pure copper plates were still expensive and short lived, thus preventing it from being more widely used. This problem was finally solved in 1832, when English industrialist George F. Muntz introduced a type of brass with an admixture of 60% copper to 40% zinc, thus called the 'Muntz metal' (or 'yellow metal'), hot rolled into thin sheathing plates.

Due to its superior mechanical properties, it was flexible enough to mold onto a ship's hull and could be used in thinner sheets, being less expensive and less corrosion prone than pure copper (Crisman & Jordan, 1999: 253; McCarthy, 2005: 115-118). The presence of copper-based sheathing together with non-ferrous plank-to-frame fasteners below the waterline dates the ship to sometime after 1780 (*terminus post quem*). Further analysis of the sheathing metal composition could provide a more precise relative dating baseline.

The composite double framing method, where several timbers were connected in pairs to create a large curved frame, is consistent with 19th-century shipbuilding practices. Basil Greenhill (1988: 115) observed that by the late 19th century many shipyards in Britain and Europe, and most yards in North America were using double composite framing, first introduced around the time of the Napoleonic Wars (1803-1815).

Regardless to the many variations in details, the system basically entailed the building of frames in pairs, each frame being made up of several members divided into floors, futtocks and top timbers, butted against one another, to compensate for the lack of suitable large compass timbers for ship construction. The paired frames were then fastened together with horizontal bolts, called frame bolts, often with chocks placed between them to allow for the circulation of air (Figure 57). In fact, decayed wooden pieces were noted lined up in between frames 7, 8, 9, 10 and 11 of Structure 1, possibly the remnants of abovementioned chocks. They were also a clear indication that frame spacing didn't change much during the wrecking process. Their precise function in the framing assembly of Structure 1, however, is not yet quite clear (Figure 58).

Castanheira (1991: 79-80) observed that this was the so-called English system, as opposed to the French system, where the frames were kept in close contact throughout. Not all shipbuilders used double composite framing, even in the late 19th century, for in cases where large naturally curved timbers were available, single frames were still in use.

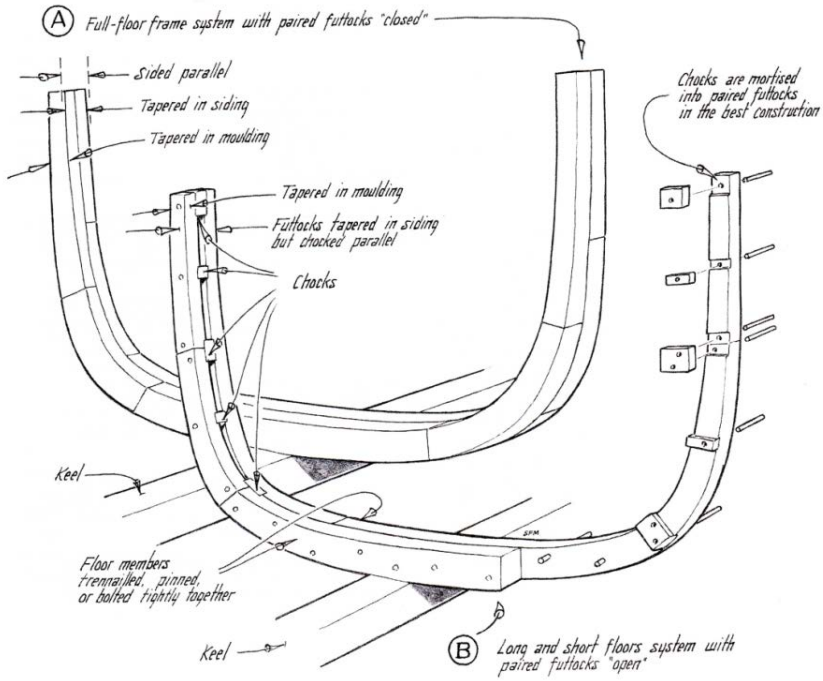


Figure 58. Schematic drawing of the two abovementioned composite double framing assemblies (modified from Greenhill, 1988: 114).

Figure 59. Detail of a possible chock found in Structure 1 between frames 8 and 9.

5. DISCUSSION

Based on the data presented in this dissertation, it is possible to consolidate the current knowledge regarding stranded shipwrecks in southern Brazil, and discuss their potential contribution to nautical archaeology and the study of shipwreck site formation processes in dynamic settings. Given the already mentioned inference issues concerning the interpretation of shipwrecks in highly dynamic depositional settings, an attempt to explore historical and nautical research questions from these sites ought to account for those aspects involved in the formation of the archaeological record. As seen here, formation process theory is not to be taken as a rigid framework, but rather as a form of scholarly approach to the archaeological record, and a way to emphasize the centrality of context in archaeology.

Generally speaking, occurrence and survival of material in the archaeological record will ultimately depend on the probability of occurrence of accidents, on the characteristics of the ship and the circumstances of the accident, and the site interaction with the environment and other cultural post-depositional processes. As it applies to formation theory, the wrecking process is segmented in pre-depositional, depositional and post-depositional processes.

Pre-depositional processes include those activities happening prior to the wreck event itself, when the shipboard community, the ship and its material culture were operating within an ongoing systemic context, thus conditioning the probability of occurrence of related archaeological information. Deposition processes, in turn, account

for characteristics and circumstances of the wrecking event, and any other factors relevant to the initial creation of the archaeological deposit, whereas post-depositional processes refers to human and environmental disturbances responsible for site alteration and variability after deposition (Muckelroy, 1978; Schiffer, 1996; and O'Shea, 2002).

Section 3 covered those aspects related to regional maritime history, and composed a background discussion on nautical technology of the 19th-century Atlantic merchant marine for the current study. It showed that the 19th century was a period of profound changes in maritime culture and nautical technology. The introduction of steam propulsion and iron hull construction established a benchmark for maritime transportation technology. This technological revolution initiated a new paradigm in maritime culture. Competition with steam and iron pushed the wooden sailing ship to the apex of its historical and technological development in terms of efficiency, hence constituting one of the greatest paradoxes in the history of global industrialization.

Moreover, the incorporation of new products, processes, and designs in a tradition-laden cultural realm such as the one of seafarers, usually produces rich opportunities for anthropological study. Although relatively well-documented, the 19th century remains an interesting research period for ship technology and nautical archaeology, particularly true when we consider the impact of technological changes and the coexistence of old and new practices in different contexts worldwide (see for example Lyman, 1967 and 1971; Hautala, 1971; Gjølberg, 1980; Hornby, 1980; Kaukiainen, 1980; Souza, 1988; Crisman & Cohn, 1998; Gould, 2001; Delis, 2012, 2014).

The shipping data for the port of Rio Grande presented in Section 3.2 provided the discussion with a sample of the nautical material culture circulating through the southwestern Atlantic during the period under analysis. This framework suggests a series of interesting research questions, pertaining to the potential expression of this seafaring culture in the archaeological record. Despite the increasing progress in steam and iron technology, the great majority of the deep-water and coastal vessels trading in southern Brazil were two-masted wooden sailing ships with capacities between 100 and 400 tons. When comparing the scantlings of the NAV Lagoa do Peixe ship with the Lloyd's scantlings and fasteners dimension lists presented in Desmond (1984: 20-21), the result suggests a ship in the range of 300 to 400 tons, with a length overall between 40m and 45m, a maximum beam between 7m and 10m, and a depth of hold around 4m. These dimensions are compatible with a large two-masted or a small three-masted sailing ship of the mid-19th century (MacGregor 1984a, 1984b).

Other potential vessels of similar range or period presented in Appendix B are the NAV Inédito, NAV Inédito B, NAV Cama de Faquir, NAV Estreito, NAV Couros, and NAV Bóia. The remains of the ship salvaged from the NAV Mostardas site, in turn, may furnish more evidence in respect to the incorporation of iron for structural members into wooden hulls, since several iron structural members were found, including iron knees, riders and diagonal straps, as well as metal sheathing and diagnostic rigging pieces.

Ships with iron or steel hulls, however, were mostly found in the surf and swash zones, making this evidence hard to see and difficult to survey, with the exception of the

NAV Dom Manuel site, which hasn't been identified, and the NM *Altair*, stranded in 1976. The ship at NAV Concheiros appears to have a fine-lined under body, suggestive of some sort of sail propulsion. The NAV Anel site, though deeply sunk into the sand, presents some diagnostic features in its preserved bottom, such as the stumps of at least two masts. According to information gathered in the archival research, it could be the wreck of the Brazilian *lugar Horácio*, sunk in the area in 1897. No evidence has yet been found of steam engines or related outfits.

As we have seen, stranding was the most common cause of maritime accidents in the coast of Rio Grande do Sul during the 19th century. Database records show that the majority of accidents correspond to ships stranded on the sand banks at the entrance to the port of Rio Grande (56.3%). In fact, the bar was a true bottleneck for the development of the port of Rio Grande and the navigation in the southern parts of the Brazilian Empire during the 19th century. The difficulties in crossing the Rio Grande bar were legendary among mariners, travelers, and consignees interested in the trade with southern Brazil.

The most commonly alleged causes for stranding were either weather related or associated with imprudence of the masters, pilots, or other crew members guiding the vessels. As we have seen, due to the shifting nature of the sand shoals at the bar entrance, and the prevailing bad weather, captains had to wait at the outside anchorages for the right conditions of tide and wind to tack in through the sand shoals. These waiting periods sometimes lasted for weeks, exposing the ships to the risk of stranding. This was the case in most recorded accidents. Difficulties in communication with the

pilot station were also an alleged reason for ships to run aground on the shoals or adjacent coast.

As seen in the case of the loss of English *patacho Hound*, a staggering number of 40 ships came to wait in the anchorages for conditions which permitted them to cross the bar during the three weeks of bad weather. In fact, this was not uncommon. Several vessels sustained damage in the hull and rigging, or lost their ground tackle. Most certainly, preparations were made with deck arrangements, and cargo and ballast distribution, in anticipation of worsening weather conditions. Communication with the pilots via the watch tower and small boats was intense but unpredictable and often dangerous. It does not come as a surprise that the database records show periodic accidents with the pilot's surf boats, which frequently involved the loss of lives.

In 1860, the British consul, Sir Henry Perengaster Vereker, writing to shipmasters in the Rio Grande trade, left an authoritative account of what was involved in the wrecking process (Vereker, 1860: 21):

> If, unfortunately, a vessel should get aground on the banks, the shipmaster should immediately call for assistance of the pilotage and steam-tug, and proceed to fix his anchors in the direction in which the vessel is most likely to float off, considering the winds, currents, and channels, and should draw upon these anchors; he should then proceed with all energy to lighten the vessel, according to the principles usually adopted. Many shipmasters, on getting aground, commence by throwing out cargo; but the effect is usually that the vessel, as it become lighter, works up higher on the shallows, and vessels have been lost from this cause, which would probably have been save had the full weight of cargo been retained.
>
> […] If the stranded vessel should break through the surface of the bank it will quickly become imbedded in the sands, an accumulation occurring also at the sides from which the breakers are driven back, thus making it often difficult to assist efficiently, or even to approach a vessel in danger; the vessel, if imbedded as above supposed, and laden with a heavy cargo, will usually sink into the sands until it may be said to be swallowed up. A remarkable illustration of this fact was shown in the case of the Helianthus, laden with coals, wrecked in 1854 on the point of the south-western bank.

> The weather being unfavorable, the vessel could not be approached. […] the brig was abandoned with ensign flying, and rigging all complete; and each day it could be observed that it had sunk further into the sands, until, finally, the tops of the masts sunk below the level of the sea.

As it concerns to the formation of the archaeological record, the wrecking process extends from the moment when preparations are made in anticipation to the accident until the moment when the ship is abandoned. In the course of the unfolding chain of events, several artifacts are expected to be jettisoned or break apart as a result of attempts to avoid the accident. Depending on the materials density, artifacts can sink or float away, and in this case, be eventually deposited elsewhere, often a nearby beach.

McNinch et al. (2006), studying artifact deposition in a similar shallow, energetic setting in North Carolina (*Queen Anne's Revenge* site), observed that wrecks in these conditions will normally settle into the sand via episodic scour processes driven by storms and inlet migration, favoring preservation of heavier artifacts and hull parts. The authors concluded that depending on the underlying geology and hydrodynamics, a shipwreck could in fact settle through several meters of substrate in highly dynamic settings. Although no systematic survey has ever been carried out in the area surrounding the sand shoals at the Rio Grande bar, shipwreck debris varying from small coal chunks to glass bottles and large timbers are frequently washed out onto the beach after storms, suggesting shipwreck remains are still being reworked (Figure 60).

Figure 60. Chunk of coal (top) from one of the many shipwrecks in the bar, washed out onto the beach after a storm. Note the shell came to rest on its stable position in relation to hydrodynamics (convex up), indicating reworking and deposition under energetic conditions.

Salvage attempts are likely to get started during abandonment. In the wrecking of the NP *Magalhães II*, the fishermen managed to take match boxes (likely some cigarettes too) wrapped in plastic bags and ropes with them. It is reasonable to think that the ship's papers, the ship's ready cash, and other small portable belongings were often disembarked during abandonment. However, given the troubled nature of the stranding process, which put the vessels in the surf area, subjected to high dynamics, attitudes toward risk may vary widely. The study of this contingent behavior yields important clues for the understanding of seafaring culture.

In one extreme we have cases such as the *Hound*, where the ship was intentionally run to the beach to avoid bigger losses. This strategy hints at a higher level of preparedness. In the other, we have the case of the NP *Magalhães II*, where the fishermen were completely unprepared for the approaching danger, so that when the ship struck the sand bank, the crew members tied themselves to a rope and jumped in the water, unaware of their location.

On a different level, seen from the shore, shipwrecks trigger another wide range of behaviors. Accounts indicate clearly that a great deal of looting started right after each storm subsided. Although mostly unpopulated, the 19th-century coastline was frequented by beachcombers and outcasts, as it still is today. In this regard, the case of the *Prince of Wales* constitutes an unfortunate, but noteworthy example. The British consul, arriving at the shipwreck site a week after the accident, described the scene (Vereker, 1863: 3-4):

> At the first light on the [June] 16th, we proceeded to the wreck, and the scene which then presented itself was melancholy in the extreme, the whole coast appeared spread with empty crates, barrels, and boxes, and with remnants of the vessel; most of these were crowded within a short distance WNW from where the hull was discovered. At this point were the longboat and gig, the oars, seamen's' chests, supply of provisions, and various parts of the rigging, with part of the figure-head (a male figure with hand outstretched), and some pieces of the hull, chiefly the after part, including furniture of cabin and berths (red velveteen), a portion of the stern with the name *Prin*. […] every case and box had been burst open and robbed of all its contents. A number had contained manufactured goods in tins, in most cases the tins had been cut open, and the contents taken away […].

Ten crew and passenger bodies were reported, including the captain's wife and daughter, who were on board with him. The circumstances of the accident were such that accusations of plundering and murder were charged by the British crown in the context

of the *Pax Brittanica*, but later denied by the Brazilian government, initiating an international diplomatic quarrel which lasted for three years, involving armed threats, and culminating with the siege of Guanabara Bay in Rio de Janeiro by the British Navy in April 1862.

Popular knowledge refers to the remains of the ship at NAV Concheiros as the *Prince of Wales* (see Appendix B). However, after careful archival research and fieldwork inspections, this possibility could be discarded on the basis of the fact that the NAV Concheiros hull was metal built, whereas contemporary documents attest otherwise, that the 315 tons *barca Prince of Wales* was entirely wooden built at a shipyard in Sunderland, UK, in 1840 (Lloyd's Register of British and Foreign Shipping, 1860).

Moreover, calls for auctioning of officially recovered items, as well as for salvage rights for the wreckage 'as found' on the beach, were a common practice following stranding events. Several cargo, rigging and outfit items were mentioned in these public calls, typically published in English and Portuguese in the local newspapers few weeks after the accidents. It is unknown, however, which hulls were actually recovered, and to what extent it was an effective business. Nonetheless, the interplay between archival research and archaeological investigation may yield further promising results in this line of inquiry.

Based on the information presented above, we may now attempt to draw an outline of the recurrent pathway for these ships to enter the archaeological record. For the sake of analytical simplicity, let us consider the stranding of a 19th-century

merchantmen as the case in focus. As we have seen, the first aspect to consider is the probability of occurrence of maritime accidents. Contrary to popular wisdom, maritime accidents are primarily a nautical technology problem. Certainly, any salty 19th-century shipmaster would have a robust toolkit of knowledge and skills embodied in his ship and crew to allow for a more or less wide range of choices to cope with an imminent natural threat.

External factors, such as an intensification of the weather system, or internal ones, such as crew management problems or equipment failure, could narrow the range of available choices, eventually reducing safety margins, but risk perception threshold and contingent reasoning should always be considered relative to given cultural and technological frameworks. Nevertheless, the importance of environmental energy for coastal navigation safety cannot be underestimated. For a reflection about endurance in the time of 'wooden ships and iron men', see for example Wallace (1937) or Villiers, (1953), or the discussion of 'cultural fracture' presented by Greenhill, 1993: 17-18).

Some of these shore stranded, broken-up ships will eventually be lost forever, and chances are that a small sample will constitute the observed archaeological record. Again, the case study of *Magalhães II* is revealing. The small trawler was relegated to abandonment when experienced fisherman Luiz Nunes Machado hired it for a low cost to fishing the southern grounds near the border with Uruguay, in the Albardão coast, a historically known area for implacable storms. At the moment of the accident, a dark night with roaring winds exceeding 70km/h, 2 to 3m waves, the cook was alone at the wheel. He tried to keep course following the 20m depth contour line. Eventually the

readings of the echo sounder started to be erratic, and all of sudden the ship was found too close to shore, where breaking waves and littoral currents overwhelmed the ship's steering and propulsion. The accident description is remarkably analogous to warnings contained in Vereker's Shipmaster's Handbook to Rio Grande do Sul (Vereker, 1860: 14-16):

> If the vessel should be coming from the River Plate it should be kept clear of the Castilhos [Uruguay] coast, and the Albardão coast should not be approached nearer than sixty miles [111km] until latitude 34° 30'S is reached, when the course may, with caution, be gradually altered more to the true north until the Rio Grande Light or Tower is discovered. […] the soundings are exceedingly irregular, and form no index of approach to the land; there appear to be various channels amid the shoals, and leading to land, which are very apt to deceive the mariner, who should take care not unnecessarily to approach this coast.

The Maritime Court process concluded that the determinant cause of the stranding was operational and that the weather, although severe, did not contribute to the outcomes (Maritime Court, Process Nº. 20.627/03). The relatively old trawler (25 years) rapidly broke apart and, in the period of a week, no integral part of the hull was there to be seen (Figure 61).

This discussion leads us now to the investigation of those aspects of site formation related to the role of environmental and cultural post-depositional processes affecting variability and survival of the archaeological record along the RSS. In an interesting study, Delgado & Murphy (1984) proposed a classification scheme for wreck sites in dynamic settings, such as near shore and beach environments, which includes three categories: *buoyant hull* sites, *buoyant hull fracture*, and *buoyant structure sites*.

Buoyant hull sites are those in which a ship comes ashore and settles into the sand, relatively intact. Buoyant hull fracture sites occur when the hull of a ship comes ashore intact, but it breaks apart on the beach and is dispersed by the surf. Buoyant structure sites, in turn, are formed when a ship breaks apart offshore and washes onto the beach in pieces.

Figure 61. Pieces of the *Magalhães II* hull, as found a week after the accident (Photos: Flávio Neves).

The case of the *Magalhães II* seems a good fit for the buoyant hull fracture type. The keel and lower hull, being stuck in the sand, causes the hull upper works to snap in the beating waves. These larger pieces will then be further broken down, following the

initial snap, until they reach an initial resting position of equilibrium in relation to prevailing hydrodynamic conditions. Since these weather systems are often coupled with storm surges, sometimes lasting up to three days, the initial hull resting position may be potentially higher up in the beach profile than it would otherwise, if stranding in calmer conditions. Other factors, such as the ship's draft, for instance, may also affect this initial resting place.

Following previously discussed theoretical responses of the beach profile's active zone during changing hydrodynamics; two idealized scenarios are presented below (Figure 62).

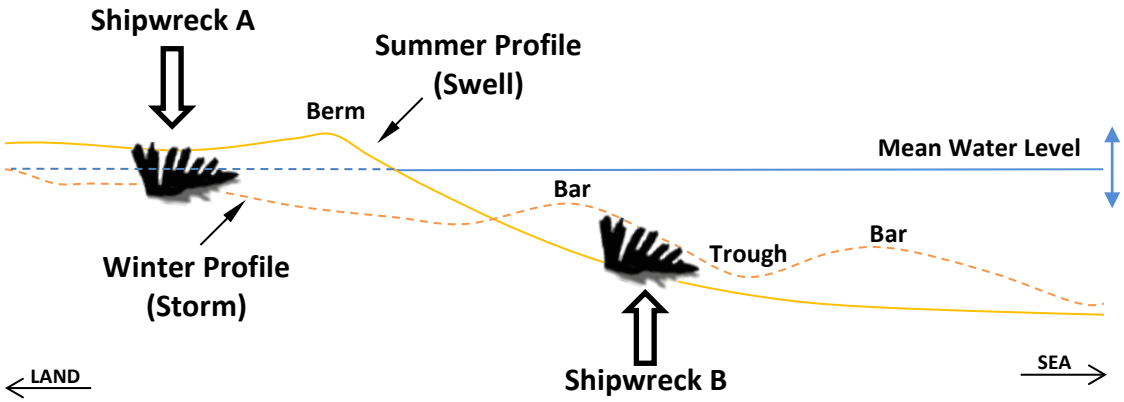


Figure 62. Generalized variations in beach profiles in response to changing hydrodynamics within the active zone of beach profile (Modified from Komar, 1983: 7). Not to scale.

During highly energetic weather and sea settings, such as the already mentioned extra-tropical cyclones and resulting storm surges, a great amount of sediments is mobilized in a short-term episodic event. As waves packed with energy reach the shore,

and the sea sets up over the beach face, the typical profile response is to reclaim sand deposited in the backshore under previously calmer conditions, carrying it away seaward. Once under water, these sediments are reworked by waves and coastal currents into characteristic longshore bars (dashed profile line). Under such conditions, shipwrecks in position A would be exposed, while those found in position B are more likely to be partially or totally covered by sediments.

During calmer conditions, waves approaching in more regular swells drive the underwater bars ashore, carrying in and accumulating sand above the swash zone. This results in a beach profile which is more concave upwards with a broad berm and steeper beach face (solid profile line). Under these conditions, sediments are carried in from underwater towards dry land, and we can expect shipwrecks placed in the backshore (position A in Figure 62) to be partially or totally covered by sediments, while those found under water (position B) are exposed. In practice, as the forces that affect the equilibrium of the nearshore zone change, the beach profile will respond to these changes in a manner that tends to restore equilibrium.

In the long term it is expected that shipwrecks along the barrier will be constantly reworked by breaking waves, coastal currents and eolian processes. Historical changes in coastal dynamics may however come to alter the relative position of the active zone of the beach profile due to the already mentioned processes of progradation or retrogradation. Chances of preservation will tend to increase during coastline progradation, whereas it will diminishes in zones of persistent erosion or retrogradation. Sometimes extreme episodic events may take the hull to a position beyond the reach of

regular seasonal disturbances. In other situations no integral fragment is left (Figure 63). Although developed for underwater settings, McNinch's model for deep artifact burial under energetic hydrodynamic conditions suggests potential preservation of artifacts in deeper strata, thus providing a start point for future probing (McNinch et al., 2001).

The scenarios discussed above are typical and correspond to highly simplified geomorphological responses in exposed sandy shores where morphodyamics are mainly dominated by waves, such as in the RSS. Given the complexity of the depositional environment, the totality of factors controlling vertical and horizontal distribution of cultural material from beach stranded shipwrecks are still unclear, so a complete model of formation processes cannot yet be proposed. The development of more robust theoretical contributions in this field must come from an approach capable of accounting for long-term trends in the displacement of ship remains in relation to environmental parameters.

In 2011, a long term monitoring experiment was set at NAV Lagoa do Peixe site, aiming at providing an empirical basis for the development of a model for beach stranded shipwreck formation processes. Two benchmarks were installed and five control points were established on each structure (see above Section 4.3.2), allowing for tridimensional surveying of wreck features in relation to the beach's profile changes (Figure 64).

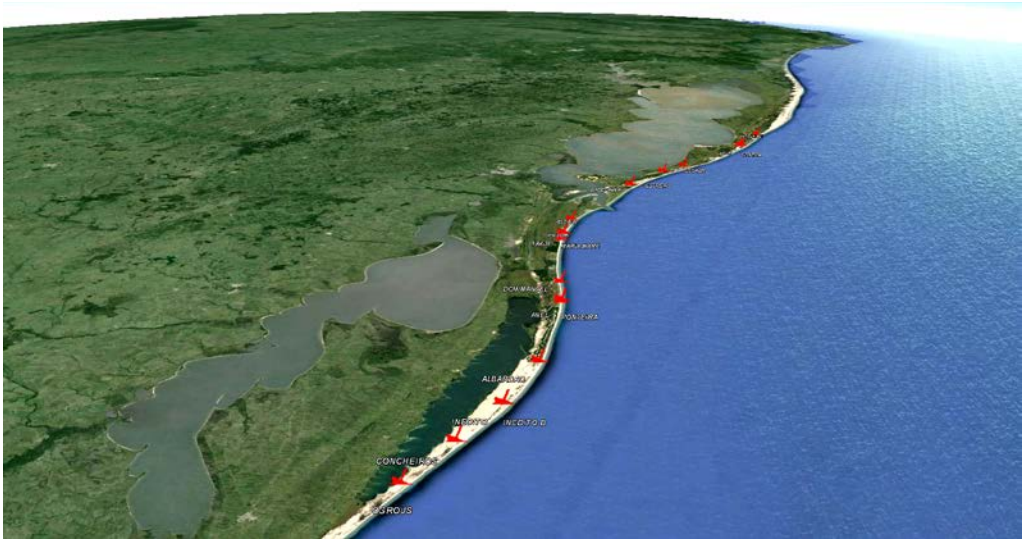


Figure 63. Oblique Google Earth satellite image showing the studied shipwreck sites distributed along the RSS barrier (Modified from Google Earth™).

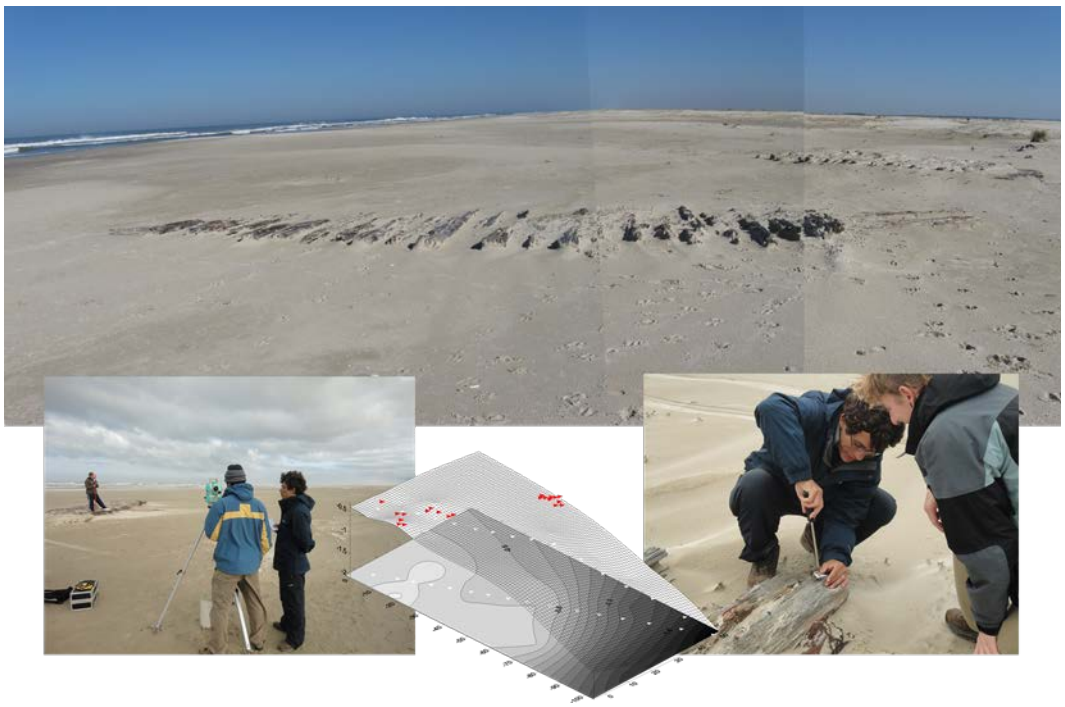


Figure 64. Monitoring experiment started in 2011 at the NAV Lagoa do Peixe site.

Observations have shown that while structures 1 and 2, situated up in the backshore, have displayed little displacement, structures 3 and 4 have moved substantially. Based in the proposed reconstruction shown in Figure 57, it is probable that structures 3 and 4 were in one piece some time ago. A comparison of pictures taken in 2006 and 2009 illustrates these changes (Figure 65). This situation was actually expected, since structures 3 and 4 are placed in the swash zone and therefore within the 'hot zone' for sediment remobilization. What is still not fully understood is the range of possible responses to changing environmental conditions. Long-term monitoring of these displacements will likely produce useful insights for the formalization of a general model for beach stranded shipwrecks.

On top of the natural processes described above, various forms of post-anthropic depositional disturbances have been observed, which affect the variability of the archaeological record. As coastal occupation grows, the chance that negative impacts from deliberate or accidental anthropic interactions with archaeological remains increases. Negative impacts verified range from vandalism, looting, intentional fires, car traffic, repurpose of timbers for hut building, and cattle trampling (Figure 66). This problem could be addressed or mitigated with government-led education campaign on the value of the nautical heritage of the region.

Figure 65. Structures 3 and 4 photographed in 2006 and 2009, showing relative displacement of structures 3 and 4 (dotted red rectangles).

Figure 66. Evidence of cattle trampling on structure 1 at site NAV Lagoa do Peixe.

6. CONCLUSIONS

From the discussions presented above, we observed that the main type of maritime accident in southern Brazil in the 19th century was caused by stranding of both deep water and coastal trade sailing vessels approaching the bar of the port of Rio Grande, or running onto the beach along the coast.

There is a verified relation between regional weather patterns and the occurrence of shipwrecks in the study area. The intensification of severe weather systems has been the most recurrent contribution factor behind these accidents, particularly during the period when ship to ship and ship to shore communications were limited. Nevertheless, shipwrecks still occur in this area, despite the fact that technology has greatly improved navigation safety.

The analysis of the pre-depositional and depositional processes involved in stranding events has shown that maritime accidents are primarily a nautical technology problem. Attitudes towards risk avoidance and contingent reasoning are greatly affected by the amount of the captain's skills and his knowledge of the ship, its crew, and the emergent situation. These attitudes ought to be considered within a given historical, cultural and technological framework. In fact, the sailing ships of the 19th century represented the pinnacle of a long technological development process in seaborne transportation, which resulted in an incredibly resourceful machine. Environmental and operational constrains, however, act to reduce the range of actual available choices, thus

reducing the safety margin for maneuver and navigation, often resulting in the loss of ships and lives.

Regardless to the presumed lack of coherence of the archaeological record in highly dynamic depositional settings, such as in the shore stranded shipwreck sites, this study indicates that the use of flexible conceptual schemes, situated in the borderline between theory and empirical data, and benefitting from the interplay between historical and archaeological data, may generate fruitful lines of inquiry. Moreover, the problem of site definition and coherence has been addressed by considering the coast of Rio Grande do Sul as single archaeological site, thus a shipwreck province, allowing for the establishment of meaningful contexts for the interpretation of the archaeological record.

Context is the raw material of archaeological inquiries. It is my understanding that the study of formation processes of the archaeological record should be taken as a 'good scientific practice' rather than a rigid framework to approach context and integrate the observed remains within significant cultural and historical research questions. Although shipwreck archaeology has come a long way in recognizing the potential of less preserved shipwreck sites, there is still some latitude for methodological developments. High energetic and dynamic shipwreck sites demand specific field procedures to account for the study of long-term patterning of the material in relation to the environment. Furthermore, wherever the remains of a ship's hull are observed, the internal logic of nautical architecture warrants a high level of informational coherence, so that, in the words of Richard Steffy (1996: 6): "*How well must a ship or a boat be preserved before a thorough study becomes necessary? There is no lower limit*."

REFERENCES

Adams, J. (2009). Comments on Keith Muckelroy: Methods, Ideas and Maritime Archaeology. **Journal of Maritime Research**. 4:83-85.

Agisoft (2014). **PhotoScan. Professional version 1.0.4, architecture 1847.** Agisoft LCC: St. Petersburg.

Alves, F das N. & Neves, H. A. P. (2001). **Náufragos e naufrágios no litoral do Rio Grande do Sul.** Coleção Pensar a História Sul-Rio-Grandense – 1. FURG: Rio Grande.

Arlington, P. (1993). The Changing Problems of Shiphandling in the Nineteenth Century. In: Gardiner, R. (Ed.). **Sail's Last Century.** Conway's History of the Ship. Conway Maritime Press Ltd: London.

Ascher, R. (1961). Analogy in Archaeological Interpretation. **Southwestern Journal of Anthropology.** 17: 317-325.

Barreto, A. (1976). **Bibliografia sul-rio-grandense.** V. 2. Conselho Federal de Cultura: Rio de Janeiro.

Bass, G. F. (ed.) (1966). **Archaeology Under Water.** Thames and Hudson: London.

_____. (1972). **A History of Seafaring Based on Underwater Archaeology.** Walker and Company: New York.

_____. (1983). A Plea for Historical Particularism in Nautical Archaeology. In: Gould, R. **Shipwreck Anthropology.** University of Mexico Press: Albuquerque.

Bicalho, H. (1884). **Melhoramento da Barra do Rio Grande do Sul: Relatório apresentado ao Governo Imperial.** Vol. I. Tipografia Nacional: Rio de Janeiro.

Binford, L. (1964). A Consideration of Archaeological Research Design. **American Antiquity**, 29:425-441.

_____. (1981). Behavioral archaeology and the 'Pompeii premise'. **Journal of Anthropological Research**, 37: 195-208.

_____. (1983). **In Pursuit of the Past: Decoding the Archaeological Record.** Thames and Hudson: London.

Bingeman, J., Bethell, J., Goodwin, P. & Mack, A. (2000). Copper and other Sheathing in the Royal Navy. **The International Journal of Nautical Archaeology.** 29.2: 218-229.

Björling, P. (1903). **Briquettes and Patent Fuel.** Rebman Limited: London.

Blunt, J. (1848). **Shipmaster´s Assistant and Commercial Digest: for Merchants, Owners and Masters of Ships.** Wiley & Putnan: Nova York.

Bojakowski, P & Bojakowski, K. (2011). The *Warwick*: results of the survey of an early 17th-century Virginia Company ship. **Post-Medieval Archaeology.** 45/1 (2011), 41–53.

Bright, L. S. (1993). Beached Shipwreck Dynamics. In: Smith, S. O. (ed.), **Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference.** Society for Historical Archaeology: Tucson. 91-94.

Britto, F. P.; Saraiva, J. M. B. (1997). Freqüência e intensidade das frentes frias em Rio Grande no mês de agosto do ano de 1996. **Anais do VII Simpósio Brasileiro de Geografia Física Aplicada.** I Fórum Latino-Americano de Geografia Física Aplicada, volume II, Curitiba, Paraná.

Burke, H. & Smith, C. (2004). **The archaeologist's field handbook.** Allen & Unwin: Crow's Nest.

Calliari, L.J., Tozzi, H. A. & Klein, A. H. (1998). Beach Morphology and Coastline Erosion Associated with Storm Surges in Southern Brazil – Rio Grande to Chuí, RS. **Annais da Academia Brasileira de Ciências.** 70 (92). 232-247.

Calliari, L. J. et al. (2006). Rio Grande do Sul. In: Muehe, D. (org.). **Erosão e progradação no litoral brasileiro.** Instituto Brasileiro do Meio Ambiente dos Recursos Renováveis. MMA: Brasília.

Camargo, A. E. de. (1868). **Quadro estatístico e geográfico da província de São Pedro do Rio Grande do Sul.** Tipografia do Jornal do Comércio: Porto Alegre.

Caminha, J. (1980). **História marítima.** Biblioteca do Exército Editora: Rio de Janeiro.

Castanheira, E. (1991). **Manual de construção do navio de madeira.** Dinalivro: Lisboa.

Castelão, G. P. & Saraiva, J. M. (1999). Análise de um Ciclone Atmosférico Sobre a Confluência Brasil-Malvinas. In: **Semana Nacional de Oceanografia. O Desenvolvimento da Oceanografia no Brasil: A Integração na Busca da Qualidade.** Rio de Janeiro. p. 354-356.

Castro, D. L. (org.) (1938). Desastres Marítimos no Brasil. In: **Subsídios para a história Marítima do Brasil.** V. I. Imprensa Naval: Rio de Janeiro.

Chaves, A. G. (1978). **Memórias ecônomo-políticas sobre a administração pública do Brasil.** ERUS: Porto Alegre.

Clarke, D. (1973). Archaeology: the loss of innocence. **Antiquity**. XLVII: 6-18.

Coli, A. B. (1994). **Análise das alturas de onda ao largo do Rio Grande do Sul: dados históricos e altimétricos.** Graduation Monography. Rio Grande.

Copstein, R. (1982). Evolução urbana do Rio Grande. **Revista do Instituto Histórico e Geográfico do Rio Grande do Sul**: Porto Alegre (122).

Costa, V. G. da (1897). **Guia de Instrucção Profissional do Marinheiro.** Imprensa Nacional: Lisbon.

Crisman, K. & Cohn, A. (1998). **When Horses Walked on Water: Horse-powered Ferries in Nineteenth-century America.** Smithsonian Institution Press: Washington.

Crisman, K & Jordan, B. (1999). Angra A: the Copper-fastened Wreck at Porto Novo. **Revista Portuguesa de Arqueologia**. 2.1: 249-254.

Crothers, W. (1997). **The American-built Clipper Ship 1850-1856.** International Marine: Camden.

Dall'Antonia Jr., A. (1991). **Vórtice de ar frio na América do Sul: Análise disgnóstico.** Master's Thesis. Instituto de Astronomia Geofísica, Universidade de São Paulo.

D'Amorin, J. P. (1841). **Diccionario de Marinha aos Officiais da Armada Nacional Portugueza.** Imprensa Nacional: Lisbon.

Daubaugh, E. (1989). **William H. Webb: Shipbuilder.** Webb Institute of Naval Architecture: New York.

Debret, J. B. (1978). **Viagem Pitoresca e Histórica ao Brasil.** Itatiaia: Belo Horizonte.

Delgado, J. (1984). Erosion-Exposed Shipwreck Remains, Winter 1982. In: Murphy, L. (ed.), **Submerged Cultural Resources Survey: Portions of Point Reyes National Seashore and Point Reyes-Farallon Islands National Marine Sanctuary.** National Park Service: Santa Fe, 179-185.

_____. (1985). Skeleton in the Sand: Documentation of the Environmentally Exposed 1856 Ship *King Philip*, San Francisco. In: Johnston, P. F. (ed), **Proceedings of the Sixth Conference on Underwater Archaeology.** Special Publication Series, N° 4. Society for Historical Archaeology.

_____. (1997). Beached Shipwreck Sites. In: Delgado, J. (ed.) In: **Encyclopaedia of Underwater and Maritime Archaeology**. British Museum Press: London, 57-59.

Delgado, J. & Murphy, L. (1984). **Environmentally Exposed Shipwreck Remains: Implications for Natural Site Formation Processes.** Paper read at the Fifteenth Annual Conference on Underwater Archaeology, Williamsburg.

Delis, A. (2012) Mediterranean Wooden Shipbuilding in the nineteenth century: Production, Productivity and Ship Types in Comparative Perspective. **Cahiers de la Méditerranée.** 84.

_____. (2014) From Lateen to Square Rig: The evolution of the Greek-owned merchant fleet and its ships in the eighteenth and nineteenth centuries. **The Mariner's Mirror**. 100:1, 44-58.

Desmond, C. (1984). **Wooden Ship-Building.** The Vestal Press LTD: New York.

DHN (2013). INT 2009: **Do Cabo de Santa Marta Grande ao Arroio Chuí, scale 1:990,526.** Brazilian Hydrography Directorate: Rio de Janeiro. Cartographic document.

Dudszus, A. & Henriot, E. (1986). **Dictionary of Ship Types. Ships, Boats and Rafts under Oar and Sail.** Conway Maritime Press: London.

Dumas, F. (1962). **Deep Water Archaeology.** Routledge: London.

_____. 1972. Ancient Wrecks. In: **Underwater archaeology. A nascent discipline.** UNESCO: Paris.

Duncan, B. (2000). **Signposts in the Sea: An investigation of the shipwreck patterning and maritime cultural landscapes/seascapes of the Gippsland Region, Victoria.** Unpublished. British Society of Science (Hons) thesis, James Cook University, Townsville, Australia.

Dunnel, R. (1992). The Notion Site. In: Rossignol, J. & Wandsnider, L. **Space, Time and Archaeological Landscapes.** Plenum Press: New York.

ESRI (2013). **ArcGIS Desktop: Release 10.2.** Environmental Systems Research Institute: Redlands. Computer software.

Fingard, J. (1982). **Jack in Port, Sailortowns of Eastern Canada.** University of Toronto Press: Toronto.

Frost, H. (1962). Submarine archaeology and Mediterranean wreck formations. **Mariner's Mirror**, 48: 82-89.

Gan, M. A. (1992). **Ciclogêneses e Ciclones sobre a América do Sul.** PhD Dissertation. Instituto Nacional de Pesquisas Espaciais.

Gan, M. A. & Rao, V. B. (1991). Surface Cyclogenesis over South America. **American Meteorological Society.** Vol. 19. 1293-1302.

Garcia, C. A. E. (1997). Environment and Biota of the Patos Lagoon estuary. Tides and Currents. In: Seeliger, U. et al. **Subtropical Convergence Environments: the coast and sea in southwestern Atlantic.** Springer-Verlag: Berlin.

Gibbs, M. (2006). Cultural Site Formation Processes in Maritime Archaeology: Disaster Response, Salvage and Muckelroy 30 Years on. **The International Journal of Nautical Archaeology.** 35.1: 4–19.

GjØlberg, O. (1980) The substitution of steam for sail in Norwegian ocean shipping 1866-1914 – a study in the economics of diffusion. **The Scandinavian Economic History Review.** 28: 2. 137-146.

Gould, R. (2001). From Sail to Steam at Sea in the Late Nineteenth Century. In: Schiffer, M. (ed.). **Anthropological Perspectives on Technology.** University of New Mexico Press: Albuquerque.

Greenhill, B. (1980). **The Life and Death of the Merchant Sailing Ship 1815-1965.** The Ship Collection. Her Majesty's Stationary Office: London.

_____. (1988). **The Evolution of the Wooden Ship.** Facts on File: New York.

_____. (1993). The Merchant Sailing Ship 1830-1930. In: Gardiner, R. (ed.). **Sail's Last Century.** Conway's History of the Ship. Conway Maritime Press Ltd: London.

Greenhill, B. & Stonham, D. (1981). **Seafaring under Sail - The Life of the Merchant Seaman.** Naval Institute Press: Annapolis.

Harpster, M. (2009). Keith Muckelroy: Methods, Ideas and Maritime Archaeology. **Journal of Maritime Research.** 4:67-82.

Harris, E. (1989). **Principles of archaeological stratigraphy.** 2nd ed. Academic Press Limited: San Diego.

Hautala, K. (1971). From Black sea to the Atlantic. Finnish merchant shipping in the late nineteenth century. **Scandinavian Economic History Review.** 19. 12-22.

Hohman, E. (1956). **History of American Merchant Seamen.** The Shoe String Press: Connecticut.

Hornby, O. (1980). The transition from sail to steam in the Danish merchant fleet 1865-1910. **The Scandinavian Economic History Review.** 28: 2. 109-134.

Inquérito Naval (2003). **Processo Nº. 20.627/03.** Tribunal Marítimo.

Johnson, J. B. (1866). In: **Atlas das obras do porto e barra do Rio Grande do Sul – histórico. Oficinas gráficas da Federação:** Porto Alegre, 1926.

Kaukiainen, Y. (1980). The transition from sail to steam in Finnish shipping 1850-1914. **The Scandinavian Economic History Review.** 28: 2. 161-184.

King, C. (1972). **Beaches and Coasts.** Edward Arnold: London.

Komar, P. D. (1983). Beach Processes and Erosion – an Introduction. In: Komar, P. D. **CRC Handbook of Coastal Processes and Erosion.** CRC Press Inc.: Boca Raton.

Lyman, J. (1967). Sailing vessel rigs in the British, American, and French Merchant Marines, 1886. **The Mariner's Mirror.** 53: 3. 231-241.

_____. (1971). Sailing vessel types in the German merchant marine, 1869. **The Mariner's Mirror.** 57: 2. 143-155.

Lobo, P. R. V. & Soares, C. A. (2007). **Meteorologia e Oceanografia.** 2nd ed. Diretoria de Hidrografia e Navegação: Rio de Janeiro.

Lloyd's Register of British and Foreign Shipping (1860). Cox & Wyman: London.

McCarthy, M. (1998). Australian Maritime Archaeology: Changes, Their Antecedents and the Path Ahead. **Australian Archaeology.** 47, 33–8.

_____. (2005). **Ships' Fastenings from Sewn Boat to Steamship.** Texas A&M University Press: College Station.

Macgregor, D. (1977). **Square Rigged Sailing Ships.** Argus Books: London.

_____. (1979). **Clipper Ships.** Argus Books: London.

_____. (1984a). **Merchant Sailing Ships 1815-1850, Supremacy of Sail.** Naval Institute Press: Annapolis.

_____. (1984b). **Merchant Sailing Ships 1850-1875. Heyday of Sail.** Naval Institute Press: Annapolis.

Machado, A. A. (2013) **Estudo dos padrões atmosféricos sinópticos geradores de eventos extremos de altura de onda, intensidade de vento, marés meteorológicas e erosão na costa do Rio Grande do Sul.** PhD Dissertation. FURG: Rio Grande.

Mappa Demonstrativo dos Navios Perdidos na Costa e Barra do Rio Grande do Sul. Author Unknown. Not dated. Original document. Archives of the Geomorphology Laboratory, Institute of Oceanogrphy, FURG.

Marone, E. & Camargo, R. (1994). Marés meteorológicas no litoral do Estado do Paraná: o evento de 18 de agosto de 1993. **Nerítica.** 8: 73-85.

McNinch, J. E., Wells, J. T. & Drake, T. G. (2001). The fate of artifacts in an energetic, shallow-water environment: scour and burial of Queen Anne's Revenge. **Southeastern Geology,** 40 (1), 19-27.

McNinch, J. E., Wells, J. T. & Trembanis, A. C. (2006). Predicting the Fate of Artefacts in Energetic, Shallow Marine Environments: an Approach to Site Management. **The International Journal of Nautical Archaeology,** 35.2: 290–309.

Microsoft. (2010**). Microsoft Excel.** Redmond, Washington. Computer Software.

Motta, V. F. (1969). **Relatório-diagnóstico sobre a melhoria e o aprofundamento do acesso pela barra do Rio Grande.** Instituto de Pesquisas Hidráulicas. Porto Alegre.

Muckelroy, K. (1975). A Systematic Approach to the Investigation of Scattered Wreck-sites. **The International Journal of Nautical Archaeology,** 4: 173-190.

_____. (1977). Historic wreck sites in Britain and their environments. **The International Journal of Nautical Archaeology and Underwater Exploration.** 6 (1): 47-57.

_____. (1978). **Maritime Archaeology.** Cambridge University Press: Cambridge.

Murphy, L. (1997). Site Formation Processes. In J. Delgado (ed.) **British Museum Encyclopaedia of Underwater and Maritime Archaeology**, British Museum Press: London.

Nobre, L. C. et al. (1986). Aspectos da climatologia dinâmica do Brasil. **Climanálise.** Special number.

O Comercial (1861). Newspaper. Archives of the Bibliotheca Rio-grandense. Rio Grande.

O'Shea, J. (2002). The Archaeology of Scattered Wreck-sites: Formation Processes and Shallow Water Archaeology in Western Lake Huron. **The International Journal of Nautical Archaeology**, 31.2: 21 1-227.

_____. (2004). The identification of shipwreck sites: a Bayesian approach. **Journal of Archaeological Science,** 31, 1533-1552.

Osório, H. (2007). **O império português no sul da América: estancieiros, lavradores e comerciantes.** Editora da UFRGS: Porto Alegre.

Paasch, H. (1988). **From Keel to Truck. A Marine Dictionary in English, French and German [...].** Ratinckx: Antwerp.

Parise, C. K., Calliari, J. & Krusch, N. (2009). Extreme Storm Surges in the South of Brazil: Atmospheric Conditions and Shore Erosion. **Brazilian Journal of Oceanography**. 57(3): 175:188.

Peterson, R. G. & Stramma, L. (1991). Upper-level circulation in the South Atlantic Ocean. **Progress in Oceanography**, vol. 266, 1-73.

Pimentel, F. (1944). **Aspectos gerais do Município do Rio Grande.** Oficina gráfica da imprensa oficial: Porto Alegre.

Priess, P. J. (2000). Historic door hardware. In: Karklins, K. **Studies in Material Culture**. The Society for Historical Archaeology. TransVisions: Uniontown.

Quinn, R., Fosythe, W., Breen, C., Boland, D., Lane, P., Omar, A. L. (2007). Process-based models for port evolution and wreck site formation at Mombassa, Kenya. **Journal of Archaeological Science**. 34, 1449-1460.

Reis, A. (1940). **Manual para as embarcações miúdas.** Imprensa Naval: Rio de Janeiro.

Relatórios do Ministério da Indústria, Viação e Obras Públicas para os anos de 1901 e 1911. Avaiable at: http://www.crl.edu/brazil/ministerial. Consulted in December, 2009.

Renfrew, C. & Bahn, P. (2008). **Archaeology: Theories, Methods, and Practice.** 5th ed. Thames & Hudson: New York.

Richards, N. (2002). **Deep Structures: An Examination of Deliberate Water Craft Abandonment in Australia.** PhD Dissertation. Department of Archaeology. Flinders University.

_____. (2003). The role of isolation in cultural site formation: a case study from Strahan, Tasmania. **Bulletin of the Australasin Institute for Maritime Archaeology**. 27: 77-84.

_____. (2004). The role of geo-politics in cultural site formation: a case study from the Northern Territory. **Bulletin of the Australasian Institute for Maritime Archaeology**. 28: 97-106.

Roteiro Brasil (1975). Diretoria de Hidrografia e Navegação. 2nd ed. Marinha do Brasil: Rio de Janeiro.

Russel, M. (2002). Beached Shipwrecks from Channel Islands National Park, California. **Journal of Field Archaeology**, Vol. 29, No. 3/4 369-384.

Sager, E. (1989). **Seafaring Labor: The Merchant Marine of Atlantic Canada 1820-1914.** McGill-Queen's University Press: Otawa.

Santos, E. (org.) (1877). **Dicionário Marítimo do Imperio Brazileiro.** Typographia e litographia Imperial, Instituto Artístico: Rio de Janeiro.

Saraiva, J. B. & Silva Dias, P. L. S.. (1996). Ciclogênese no Litoral Sul do Brasil: Estudo de Caso. In**: Congresso Brasileiro de Meteorologia.** 9. Anais. Campos do Jordão. 779-782.

Schiffer, M. (1972). Archaeological Context and Systemic Context. **American Antiquity** 37:156-165.

_____. (1976). **Behavioral Archeology.** Academic Press: New York.

_____. (1996). **Formation Processes of the Archaeological Record.** University of Utah Press: Salt Lake City.

Schiffer, M. & Rathje, W. (1973). Efficient exploitation of the archeological record: penetrating problems. In: Redman, C. (ed.) **Research and theory in current archeology**, pp. 169-179.Wiley: New York.

Short, A. D. & Hesp, P. A. (1982). Wave, Beach and Dune Interactions in Southeastern Australia. **Marine Geology**. 48: 259-284.

Smith, H., Barto Arnold, J., & Oertling, T. (1987). Investigation of a Civil War Anti-torpedo Raft on Mustang Island, Texas. In: **The International Journal of Nautical Archaeology and Underwater Exploration.** 16: 149-157.

Souza, D. (1998). **The Persistence of Sail in the Age of Steam: Underwater Archaeological Evidence from the Dry Tortugas.** Plenum Press: New York.

Stewart, D. (1999). Formation Processes Affecting Submerged Archaeological Sites: an Overview. **Geoarchaeology: an International Journal**. Vol. 14, No. 6, 565-587.

Steffy, R. (1996). **Wooden Ship Building and the Interpretation of Shipwrecks.** Texas A&M University Press: College Station.

Tchernia, P. (1980). **Descriptive Regional Oceanography.** Pergamon Marine Series Volume 3. Pergamon Press: Oxford.

Torres, R. O. (2010). **… e a modernidade veio a bordo: Arqueologia histórica do espaço maritimo oitocentista na cidade do Rio Grande/RS.** Master's Thesis. Universidade Federal de Pelotas. Brazil.

Underhill, H. (1946). **Masting and Rigging the Clipper Ship & Ocean Carrier.** Brown, Son and Ferguson Ltd.: Glasgow.

UNESCO. (1972). **Underwater archaeology. A nascent discipline.** UNESCO: Paris.

Vereker, H. P. (1860). **Shipmaster's Handbook to Rio Grande do Sul.** Effingham Wilson, Royal Exchange: London.

_____. (1863). **The Brazil Correspondence in the Case of the "Prince of Wales" and Officers of the "Forte".** William Ridgway: London.

Ville, S. (1987). **English Shipowning during the Industrial Revolution.** Manchester University Press: Cornwall.

_____. (1993). The Transition to Iron and Steel Construction. In: Gardiner, R. (ed.). **Sail's Last Century.** Conway's History of the Ship. Conway Maritime Press Ltd: London.

Villiers, A. 1953. **The way of a ship; being some account of the ultimate development of the ocean-going square-rigged sailing vessel, and the manner of her handling, her voyage-making, her personnel, her economics, her performance, and her end.** Scribner: New York.

Wallace, F. 1937. **Wooden Ships and Iron Men. The story of the square-rigged merchant marine of British North America, the ships, their builders and owners , and the men who sailed them.** George Sully & Company: New York.

Ward, I., Larcombe, P. & Veth, P. (1999). A New Process-bases Model for Wreck Site Formation. **Journal of Archaeological Science**. 26, 561-570.

Ward, I. & Larcombe, P. (2002). A process-orientated approach to archaeological site formation: application to semi-arid Northern Australia. **Journal of Archaeological Science**. 30, 1223-1236.

Westerdahl, C. (1992). The maritime cultural landscape. **The International Journal of Nautical Archaeology.** 21.1: 5-14.

Wheeler, A. (2002). Environmental Controls on shipwreck preservation: The Irish context, **Journal of Archaeological Science.** 29, 1149–59.

Willey, G. & Philips, P. (1958). **Method and Theory in American Archaeology.** University of Chicago Press: Chicago.

Young, A. (1863). **Nautical Dictionary [...].** 2nd ed. Longman, Green, Roberts, & Green: London.

APPENDIX A

Ship Types

Below is presented a tentative translation of the references to ship types in the archival documents consulted and mentioned in the present study, with focus on merchantmen. The entries are organized starting with three-masted ships and ending in one-masted ships. Regional and temporal variations in the names given to ships and boats are common in Portuguese dictionaries, and therefore this glossary is tentative. The translation of ship types between Portuguese and English 19th-century nautical traditions does certainly demand a more thorough study, considering the specificities of each type individually.

The main sources used in this translation were:

Costa, Victorino Gomes da (1897). **Guia de Instrucção Profissional do Marinheiro.** Imprensa Nacional: Lisbon.

D'Amorin, João Pedro (1841). **Diccionario de Marinha aos Officiais da Armada Nacional Portugueza.** Imprensa Nacional: Lisbon.

Dudszus, Alfred & Henriot, Ernest (1986). **Dictionary of Ship Types. Ships, Boats and Rafts under Oar and Sail.** Conway Maritime Press: London.

Macgregor, David (1984a). **Merchant Sailing Ships 1815-1850, Supremacy of Sail.** Naval Institute Press: Annapolis.

Paasch, Hans (1988). **From Keel to Truck. A Marine Dictionary in English, French and German [...].** Ratinckx: Antwerp.

Reis, Amphiloquio (1940). **Manual para as embarcações miúdas.** Imprensa Naval: Rio de Janeiro.

Santos, E. (org.) (1877). **Dicionário Marítimo do Imperio Brazileiro.** Typographia e litographia Imperial, Instituto Artístico: Rio de Janeiro.

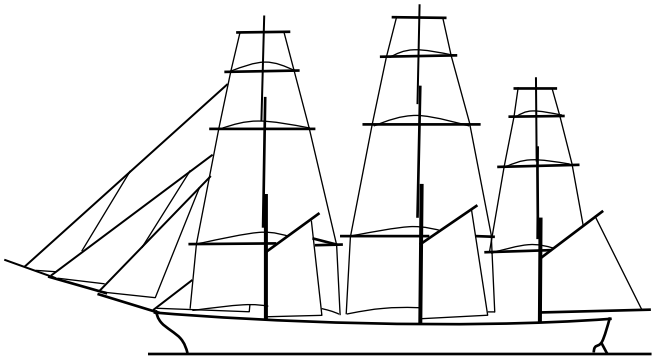
Underhill, Harold (1946). **Masting and Rigging the Clipper Ship & Ocean Carrier.** Brown, Son and Ferguson Ltd.: Glasgow.

Young, Arthur (1863). **Nautical Dictionary [...].** 2nd ed. Longman, Green, Roberts, & Green: London.

THREE-MASTED SHIPS

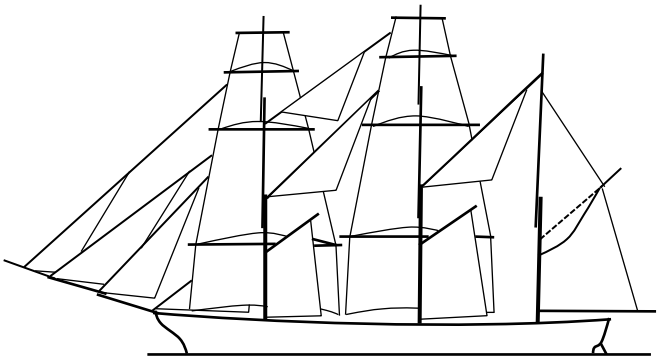
GALERA: Full-rigged ship

Normally simply referred to as *ship* in English, it was square rigged on all its three masts. It set a gaff sail, called the spanker, from its mizzen lower mast. There were tops on all three lower masts carrying square sails. Full-rigged merchantmen typically carried no spencers, but staysails between masts instead (Costa 1898: 113-114).



BARCA (also brigue-barca): Bark (US); Barque (UK)

Three-masted vessel having her fore and main masts square rigged like those of a ship, but her mizzen mast was lateen rigged with gaff topsail.



LÚGAR (also *lugre*): Barquetine; Three-masted schooner; Lugger

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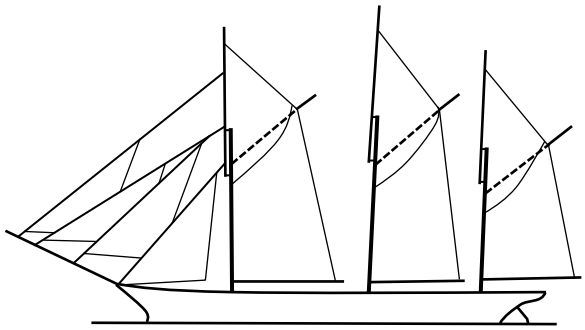
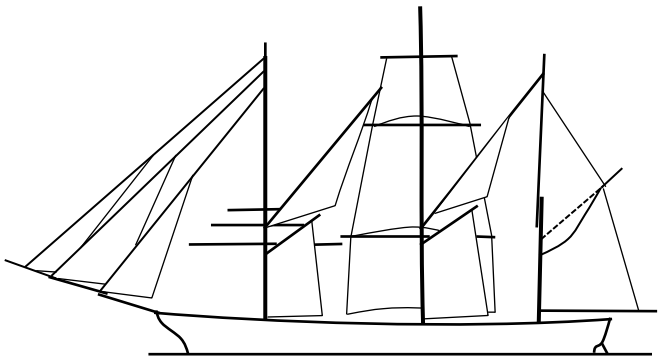


Fine three-masted vessel, with mizzen, main and fore-masts, besides a bowsprit. Main and mizzen masts bent lateen sails with gaff topsails. When the foremast was rigged with square sails, it was thus referred as a barquetine in English. When bending a lateen sail in the foremast it was more properly called *a lúgar-escuna*, in Portuguese, or three-masted topsail schooner in English. In the latter case, the fore top and topgallant masts were normally a single pole. In some instances the *lúgar* was also mentioned to carry only lateen sails on its three masts (Costa, 1898: 116), thus it could be referred in English as a three-masted schooner.

POLACA: Polacre



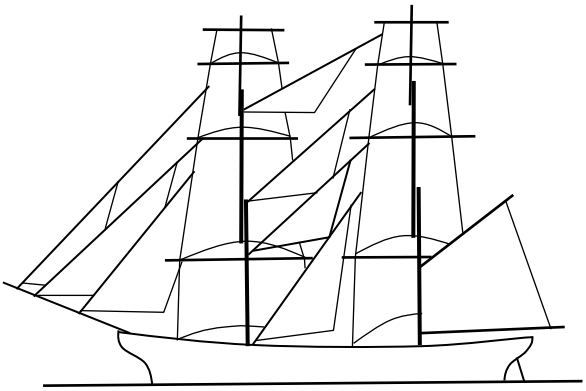
Typical in the Mediterranean, the polacre rig distinctive feature was that the square-rigged masts were in a single pole from hell to truck without crosstrees, and the upper yards lowered close down to the lower yard, resulting in a less cumbersome rig, thus saving crew, spars and gear. It first appeared in the 18th century, but became popular

around 1840's as falling freights forced greater economies on all classes of vessels (Macgregor, 1984: 123 and 130; Underhill, 1946: 232; Santos, 1877: 159). There were polacres of two or three masts. A polacre-brig, for example, was rigged like a brig, with the exception that the lower masts had no tops or caps, being in one length with the topmasts (Paasch, 1888: 2).

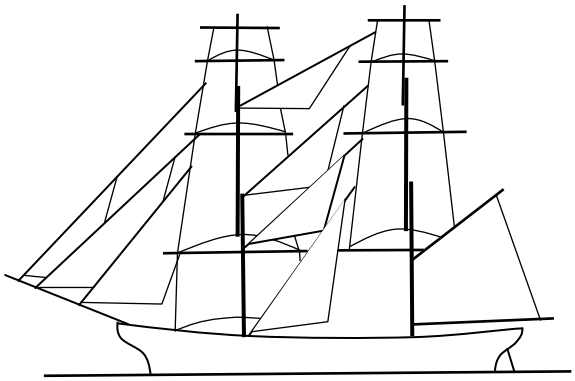
TWO-MASTED SHIPS

BRIGUE: Brig

Two-masted ship, square-rigged on both masts. Like a full rigged ship, it also set a spanker, in the case on her main lower mast. Quite often this spanker was set on a small mast stepped immediately abaft the main lower mast, thus called a *snow* in English.



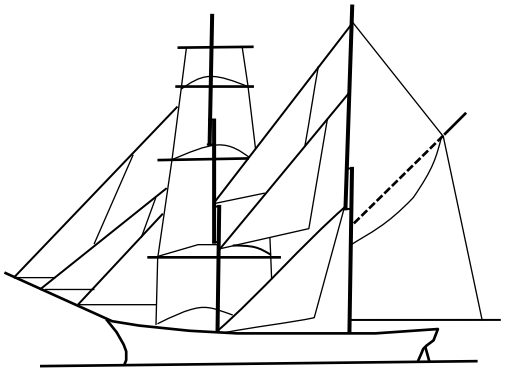
BERGANTIN: Brigantine; True brigantine



Name given to 18th and early 19th-century brigs which did not carry main square sail, but only main topsails (Santos, 1877: 34). In the beginning of the century, the terms brigantine, schooner-brig and brig-schooner were almost synonymous in English. The name 'true brigantine' was used in the mid to late 19th-century in contrast to hermaphrodite brig (see *patacho* below) (Dudszuz & Henriot, 1986: 59-60).

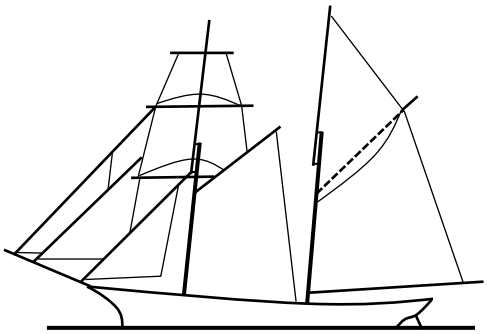
BRIGUE-ESCUNA: see *bergantin*

PATACHO: Brigantine; Hermaphrodite brig



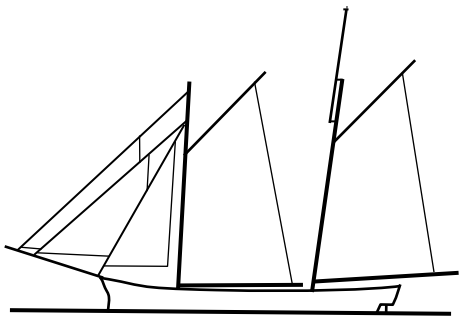
Two-masted ship where the foremast is square-rigged and the main mast, which is taller, is lateen-rigged with a gaff topsail. Sometimes carried small square sails aloft at the main mast.

ESCUNA: Schooner



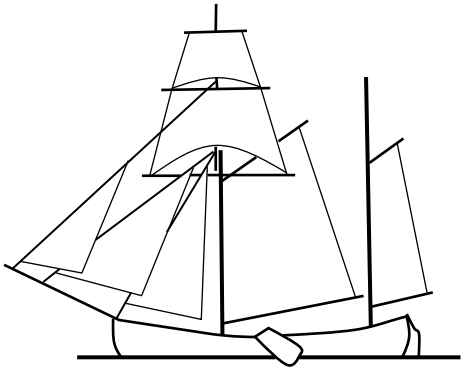
Two-masted vessel where the mainsail and foresail are lateen rigged, set on a gaff and booms, being the main mast somewhat taller than the foremast. A fore-and-aft schooner could have a cross-jack yard on which a square sail was set when required, all other sails being fore-and-aft. A topsail schooner carried a square fore topsail, and frequently also a square topgallant and royal at the fore mast. A topsail schooner differed from the brigantine for having only a fore topmast, no stay sails in between masts, and only a jib-boom extending out the bowsprit.

HIATE: Pilot schooner



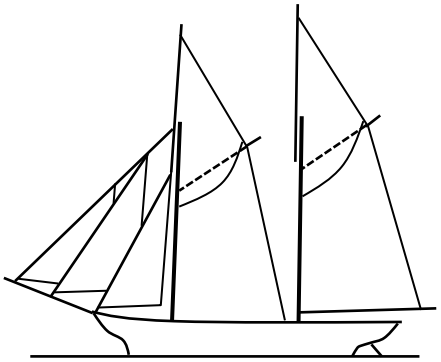
Two-masted vessel, lateen rigged, where the main and fore sails are set on gaff and booms, most commonly bending no gaff topsails. The main mast is raked, with the boom extending aft past the stern, and fiddled with a flagstaff on top called “pau de combate”, in Portuguese (Costa, 1898: 116). In some cases could carry a square topsail in the foremast (Santos, 1877: 103).

GALEOTA: Galliot



A fairly flat-bottomed vessel, whose bow and stern are similar, being round and bluff. It was commonly fitted with lee boards, and had two masts. The foremast, which was the tallest, was rigged like a cutter. The aft mast carried a sail which, like the foremast sail, was set upon a boom and gaff. Drawing little water, it was especially common in Holland (D'Amorim, 1841: 168-169; Young, 1863: 166; Santos, 1877: 95).

PALHABOTE: Pilot-boat; Fore-and-aft schooner



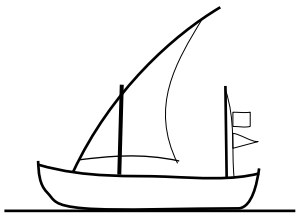
Two-masted vessel, fine and seaworthy, in which the main mast, with its boom extending aft past the stern, raised higher than the foremast. Its large sail area was complete with a bowsprit carrying fore staysail, jib and flying jib. For fair winds could carry a square sail on its foremast (Costa, 1898: 116). *Palhabote* is a corrupted term for Pilot-boat, in English.

SUMACA: Smack (?)

Small two-masted vessel rigged as a *patacho*, typical in the coastal trade along the coast of Brazil and River Plate. The foremast was polacre-rigged and the main mast rigged as the foremast of a topsail schooner (D'Amorim: 1841: 284-285; Santos, 1877: 185). An elusive ship type, the *sumaca* has never been described in detail regardless of its ubiquitous presence in Western Atlantic waters. The translation to smack was suggested in Santos (1877: 185), but it does not seem to correspond to the English term (see for example Young, 1863: 358).

ONE-MASTED SHIPS

CATRAIA: Pilot surf boat

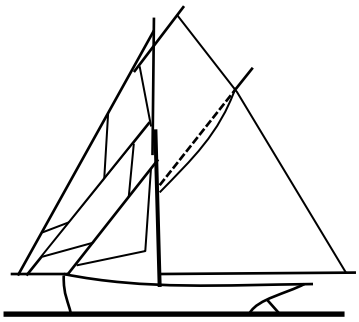


Small boat without a transom panel, strongly built, employed in port service and fisheries. In the port of Rio Grande was employed by pilots to guide ships demanding the port through the sand banks in the bar entrance.

LANCHA: Launch

Largest of the ship's boats, powered by sails and/or oars. Employed for varied duties, including setting the ship's large anchors, tending cargo and water.

*CÚTE*R: Cutter



Single-masted vessel, rigged with large lateen sail and gaff topsail, and a large near-horizontal retractable bowsprit, bending forestay sail and jib. It could carry a square sail and yard used in fair winds.

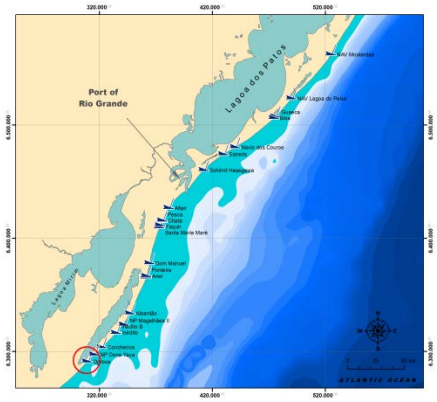
APPENDIX B

SITE NAME: NAV Ógrous

COORDINATES:

UTM 22S 310,020.675E 6,291,324.356N

LOCATION:



OBSERVATIONS:

Small metal-built vessel. Few metal frames, rarely appear in the breaker zone.

PHOTOS:

Figure 67. NAV Ógrous as seen in July 2011.

Figure 68. Early undated picture of NAV Ógrous in the beach (Coastal Atlas Project, IO/FURG).

Figure 69. Early undated picture of NAV Ógrous in high water (Coastal Atlas Project, IO/FURG).

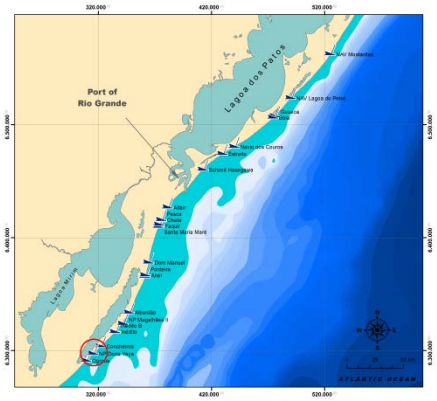
SITE NAME: NP *Dona Yayá*

COORDINATES:

UTM 22S 310,020.675E

6,291,324.356N

LOCATION:



OBSERVATIONS:

Modern wooden fishing trawler, stranded in 1992 at night due to an error in navigation. After being pulled up to the beach, it was broken down by local population.

PHOTOS:

Figure 70. NP *Dona Yayá* recently stranded (Coastal Atlas Project, IO/FURG).

Figure 71. NP *Dona Yayá* as seen a year after it stranded (Coastal Atlas Project, IO/FURG).

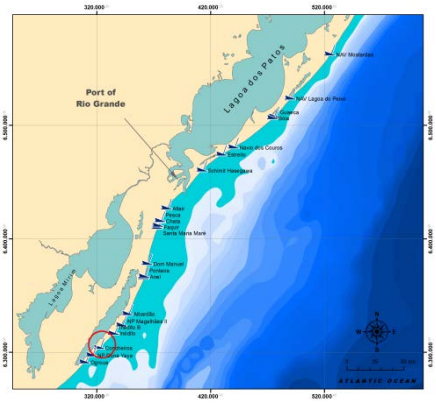
Figure 72. NP *Dona Yayá*as seen in 2011.

SITE NAME: NAV Concheiros

COORDINATES:

UTM 22S 322,402.293E 6,304,175.082N

LOCATION:



OBSERVATIONS:

Lower hull portion of fine-lined metal ship of large size. Located in the swash zone. Rarely seen.

PHOTOS:

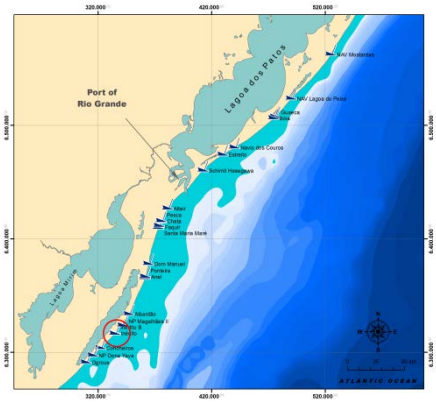
Figure 73. NAV Concheiros as seen in October 2007.

SITE NAME: NAV Inédito B

COORDINATES:

UTM 22S 334,697.365E 6,316,283.314N

LOCATION:



OBSERVATIONS:

Partially exposed wooden frames, iron fasteners and rigging outfits. Observed for the first time in 2013, near the field of incipient dunes.

PHOTOS:

Figure 74. Partial view of site NAV Inédito B, as seen in 2013.

Figure 75. Naturally exposed iron fasteners observed at the NAV Inédito B site in 2013.

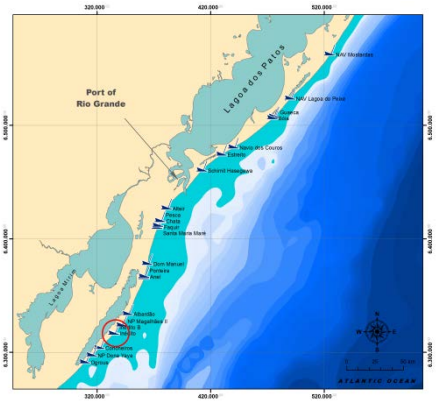
Figure 76. Other naturally exposed iron fasteners observed at the NAV Inédito B site in 2013.

SITE NAME: NAV Inédito

COORDINATES:

UTM 22S 334,919.616E 6,316,561.127N

LOCATION:



OBSERVATIONS:

Consists of dismembered parts of a possible 19th century wooden hull, scattered high up in the dune field. First seen in 2003. The largest articulated piece was partially excavated in 2013.

PHOTOS:

Figure 77. Main structure at NAV Inédito site, as seen in 2003.

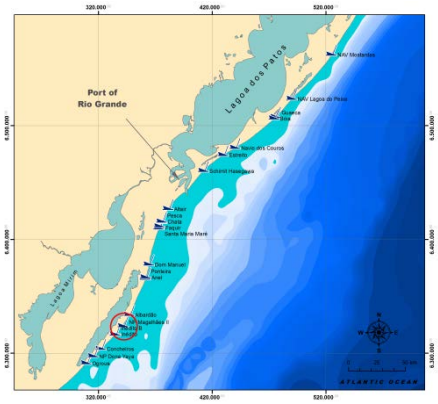
Figure 78. Main structure at NAV Inédito site, as excavated in 2013.

SITE NAME: NP *Magalhães II*

COORDINATES:

UTM 22S 341,703.546 6,323,461.474

LOCATION:



OBSERVATIONS:

Modern wooden fishing trawler, stranded at Albardão beach in 2003, due to a storm combined with negligence of the ship's captain. Completely broken, it was salvaged by local population.

PHOTOS:

Figure 79. NP *Magalhães II* in the morning after stranding in 2003.

Figure 80. Another view of NP *Magalhães II* in the morning after stranding in 2003.

SITE NAME: NAV Ponteira

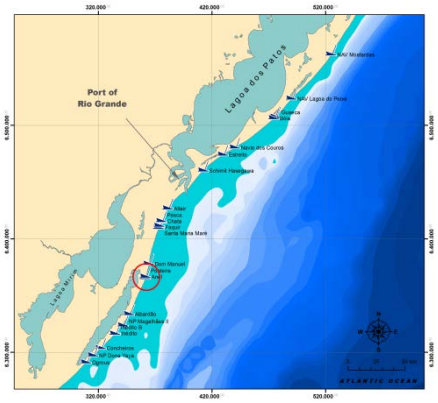
COORDINATES:

UTM 22S 361,087.338E 6,365,195.755N

OBSERVATIONS:

Modern wooden fishing trawler, situated at the breaker zone.

LOCATION:



PHOTOS:

Figure 81. NAV Ponteira as seen in the breakers in 2003.

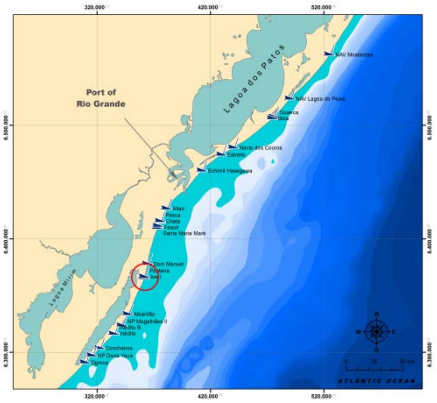
Figure 82. NAV Ponteira as seen much degraded in 2011.

SITE NAME: NAV Anel

COORDINATES:

UTM 22S 361,484.213E 6,366,584.821N

LOCATION:



OBSERVATIONS:

Large metal built ship, possibly masted, extending approximately 50m into the breaker zone. Rarely seen.

PHOTOS:

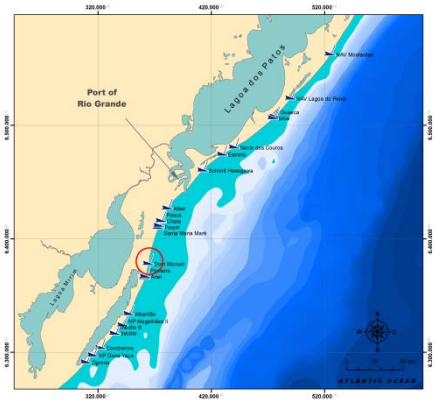
Figure 83. NAV Anel as seen in a rare event of low water in 2003.

SITE NAME: NAV Dom Manuel

COORDINATES:

UTM 22S 364,027.771E 6,377,491.237N

LOCATION:



OBSERVATIONS:

Large modern metal ship, extending across the swash zone.

PHOTOS:

Figure 84. NAV Dom Manuel site at unknown date, seen from the stern (Coastal Atlas Project, IO/FURG).

Figure 85. Dom Manuel seen with the starboard side exposed at an unknown date (Coastal Atlas Project, IO/FURG).

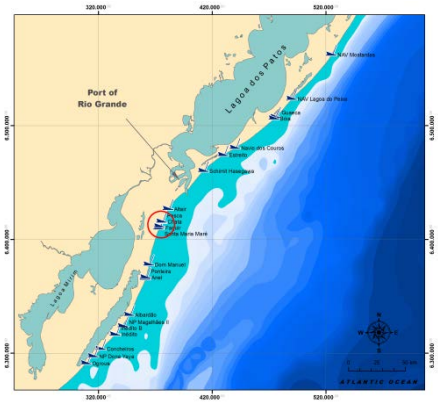
Figure 86. Dom Manuel site as seen in 2011, completely covered.

SITE NAME: NAV *Santa Maria Maré*

COORDINATES:

UTM 22S 372,942.509E 6,409,482.527N

LOCATION:



OBSERVATIONS:

Modern wooden fishing vessel caught on fire and stranded in the 1940's.

PHOTOS:

Figure 87. Fishing vessel *Santa Maria a Maré*, seen here in the Port of Rio Grande at unknown date (Coastal Atlas Project, IO/FURG).

Figure 88. NAV *Santa Maria a Maré* site. Unknown date (Coastal Atlas Project, IO/FURG).

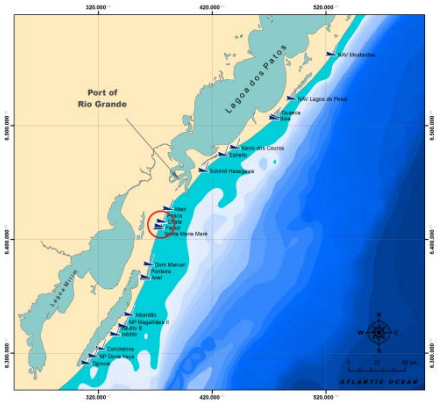
Figure 89. NAV *Santa Maria a Maré* site as seen in 2011.

SITE NAME: NAV Cama de Faquir

COORDINATES:

UTM 22S 373,652.277E 6,411,348.558N

LOCATION:



OBSERVATIONS:

Remains of a large wooden ship heavily fastened with iron bolts. Unidentified. Situated in the high swash zone, near the field of incipient dunes.

PHOTOS:

Figure 90. Site NAV Cama de Faquir, working as sediment trap for dunes formation. Unknown date (Coastal Atlas Project, IO/FURG).

Figure 91. Site NAV Cama de Faquir as seen in 2011.

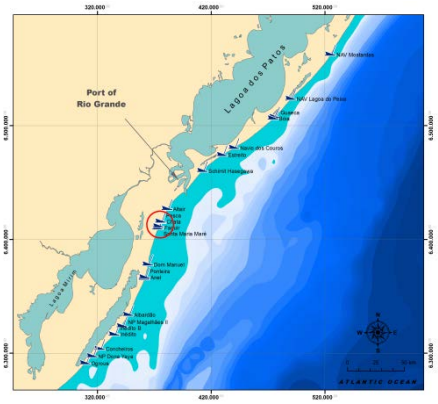
Figure 92. Detail of test pit excavated in 2007, showing the large frames, outer planks, and diagnostic iron bolts (scale of 0.15m).

SITE NAME: NAV Pesca 1

COORDINATES:

UTM 22S 375,284.777E 6,414,946.746N

LOCATION:



OBSERVATIONS:

Remains of modern wooden fishing vessel.

PHOTOS:

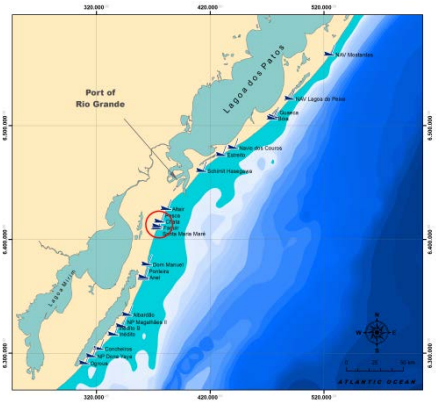
Figure 93. Site NAV Pesca 1 as seen in 2001.

SITE NAME: NAV Chata

COORDINATES:

UTM 22S 375,602.278E 6,415,502.372N

LOCATION:



OBSERVATIONS:

Remains of unknown metal vessel or container.

PHOTOS:

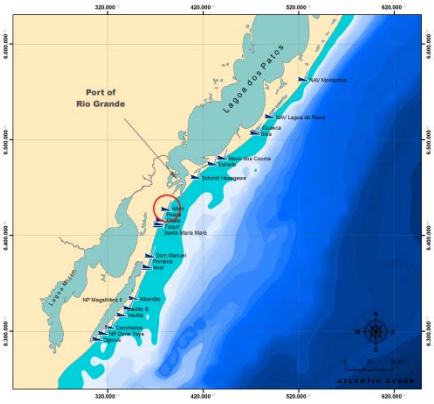
Figure 94. Site NAV Chata as seen in 2011.

SITE NAME: NM *Altair*

COORDINATES:

UTM 22S 381,117.756E 6,428,057.915N

LOCATION:



OBSERVATIONS:

Modern merchantman intentionally stranded in a storm in June 1976, in route from Buenos Aires to Natal via Rio de Janeiro with cargo of corn.

PHOTOS:

Figure 95. NM *Altair* after its stranding in 1976.

Figure 96. NM *Altair* site as seen in 2007.

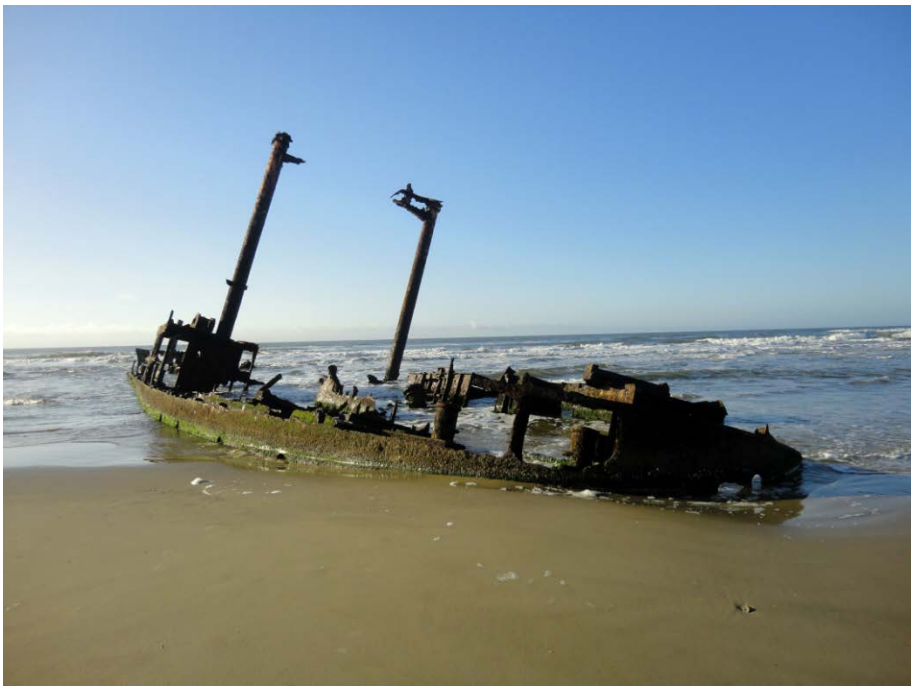


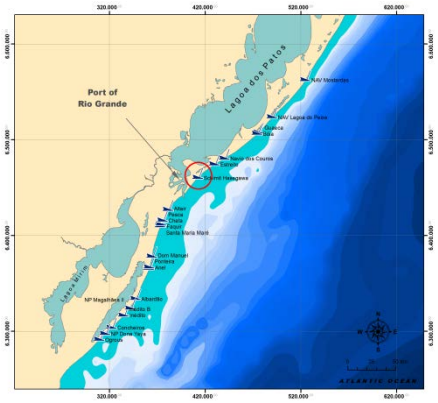
Figure 97. NM *Altair* site as seen in 2011.

SITE NAME: NP *Schmitt Hasegawa II*

COORDINATES:

UTM 22S 411,449.279E 6,461,097.611N

LOCATION:



OBSERVATIONS:

Modern wooden fishing vessel stranded in 1996 after losing ground tackle.

PHOTOS:

Figure 98. NP *Schmitt Hasegawa II* after its stranding in 1996 (Coastal Atlas Project, IO/FURG).

Figure 99. NP *Schmitt Hasegawa II* as seen in 2002.

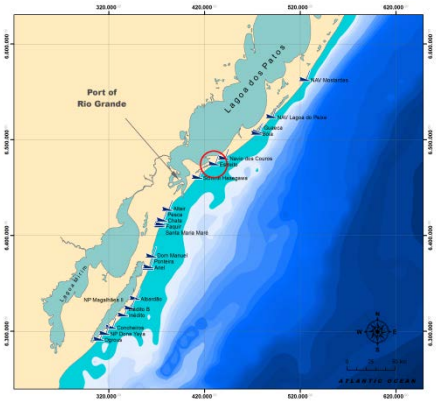
Figure 100: NP *Schmitt Hasegawa II* as seen in 2007.

SITE NAME: NAV Estreito

COORDINATES:

UTM 22S 430,406.482E 6,474,638.469N

LOCATION:



OBSERVATIONS:

Remains of wooden vessel with copper alloy fasteners.

PHOTOS:

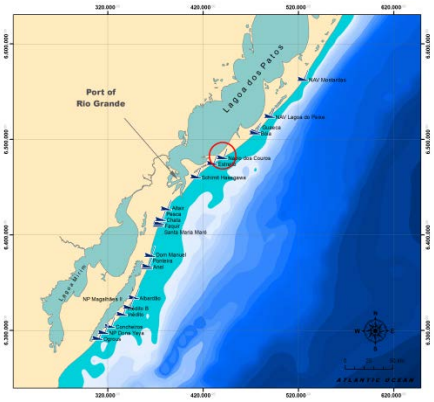
Figure 101. NAV Estreito as seen in 2009.

SITE NAME: NAV Navio dos Couros

COORDINATES:

UTM 22S 439,614.265E 6,481,679.716N

LOCATION:



OBSERVATIONS:

Few remains of wooden vessel with iron fasteners and concretions, known to have a cargo of leather.

PHOTOS:

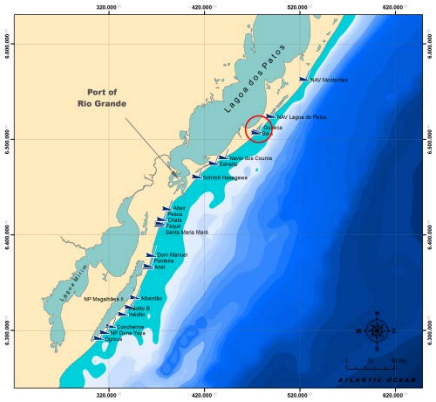
Figure 102. Test pit at NAV Navio dos Couros site excavated in 2003, showing exposed timber fragments.

SITE NAME: NAV Bóia

COORDINATES:

UTM 22S 474,327.101E 6,506,037.101N

LOCATION:



OBSERVATIONS:

Remains of wooden vessel with iron, copper alloy and plugged treenails. Double composite framing pattern.

PHOTOS:

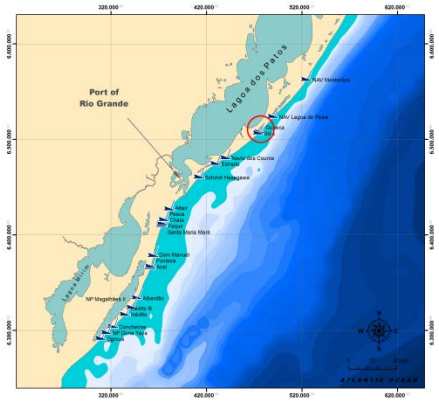
Figure 103. NAV Bóia site as seen in 2009.

SITE NAME: NP *Guaeca*

COORDINATES:

UTM 22S 475,716.166E 6,507,492.312N

LOCATION:



OBSERVATIONS:

Modern wooden fishing vessel stranded in 1994 as a result of navigation mistakes during a storm.

PHOTOS:

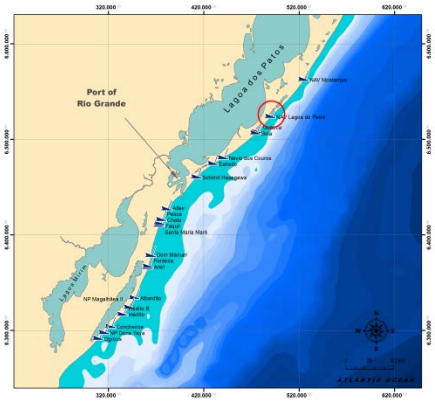
Figure 104. NP *Guaeca* in the swash zone. Unknown date (Coastal Atlas Project, IO/FURG).

SITE NAME: NAV Lagoa do Peixe

COORDINATES:

UTM 22S 488,902.991E 6,523,927.195N

LOCATION:



OBSERVATIONS:

Four structured remains of a wooden vessel with iron, copper alloy and wedged treenails. Double composite framing pattern with frame bolts. Metal sheathed. Partially excavated in 2013.

PHOTOS:

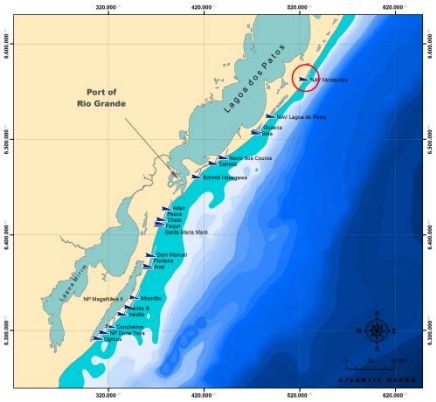
Figure 105. Partial view of NAV Lagoa do Peixe site as seen in 2009.

SITE NAME: NAV Mostardas

COORDINATES:

UTM 22S 525,192.493E 6,561,841.600N

LOCATION:



OBSERVATIONS:

Remains of a sailing wooden vessel salvaged from the beach in 1996. Presence of bronze, iron and plugged treenails fasteners. Iron knees. Metal sheathing. Double composite framing pattern with frame bolts.

PHOTOS:

Figure 106. Remains of NAV Mostardas during salvage operations by local authorities in 1996.