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SEEKING A COMMON GROUND FOR THE NAUTICAL ARCHAEOLOGY DIGITAL LIBRARY (NADL). REFLECTIONS ON SCIENCE, METHOD, THEORY AND TEMPLATES

EN BUSCA DE UN HORIZONTE COMÚN PARA LA BIBLIOTECA DIGITAL DE ARQUEOLOGÍA NÁUTICA (NADL). REFLEXIONES SOBRE CIENCIA, MÉTODO, TEORÍA Y PLANTILLAS

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Highlights:

- Standardization of data allows robust comparative and inter-subjective analysis of coastal and maritime projects, shipwrecks and nautical technology.
- Research is strongly benefited by sharing information underlying publications and raw data generated within a project in open source platforms.
- Digital databases such as NADL enhance cooperative research, as well as teaching and outreach strategies.

Abstract:

Data sharing is a fundamental process for the advancement of both natural and social sciences. Starting from the idea that computers and the internet have drastically changed the world in the last decades, this paper advocates for the creation of a space where archaeologists from around the world can share information about maritime history and exchange data with colleagues. Following the principles of open access, we argue that raw data publication is necessary and significant for the development and democratization of the discipline. This study explains the fundamental aspects of the Nautical Archaeology Digital Library (NADL) and its efforts to standardize information collection for shipwrecks and related sites, so that scholars can create a community to disseminate both raw data and complete information in the field of maritime archaeology. To achieve this, our purpose is to facilitate the development of common-ground methodology and terminology that promotes an intelligible dialogue within the global community of nautical archaeologists. This paper addresses some considerations on terminology and systematization in scientific disciplines and discusses the theoretical and methodological issues linked to the process of making a template for recording shipwrecks. Furthermore, this article analyses some of the problems related to the standardization of description processes and the necessity to create a flexible system that accounts for data diversity. The third section discusses how science is greatly enhanced by publishing information in open access platforms.

Keywords: standardization; primary data; open-source publication; nautical archaeology; maritime archaeology; digital archaeology

Resumen:

Compartir información es un proceso fundamental para el desarrollo de las ciencias naturales y sociales. Partiendo de la idea de que las computadoras e Internet han cambiado drásticamente el mundo en las últimas décadas, este trabajo

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aboga por la creación de un espacio en el que arqueólogos de alrededor del mundo puedan compartir información sobre historia marítima e intercambiar datos con otros colegas. Siguiendo los principios del libre acceso, sostenemos que la publicación de datos en bruto es necesaria y significativa para el desarrollo y democratización de la disciplina. Este artículo explica los fundamentos de la Biblioteca Digital de Arqueología Náutica (NADL) y sus esfuerzos por estandarizar el registro de la información sobre naufragios y sitios relacionados, para que los investigadores puedan crear una comunidad de divulgación, tanto de datos primarios como de información completa en el campo de la arqueología marítima. Para lograrlo, nuestro propósito es contribuir al desarrollo de una metodología y terminología comunes que promuevan un diálogo inteligible entre la comunidad global de arqueólogos náuticos. En este artículo presentamos algunas consideraciones sobre la terminología y la sistematización en las disciplinas científicas y discutimos los problemas teóricos y metodológicos vinculados al proceso de creación de una plantilla para el registro de naufragios. Además, reflexionamos sobre algunos de los problemas relacionados con la estandarización de los procesos descriptivos y la necesidad de crear un sistema flexible que refleje la diversidad de los datos. Finalmente, se analiza cómo la ciencia se ve enormemente favorecida por la publicación de información en plataformas de libre acceso.

Palabras clave: estandarización; datos primarios; fuente abierta; arqueología náutica; arqueología marítima; arqueología digital

1. Introduction

The digital realm of the 21st century created new possibilities for collaborative and interactive environments. New forms of knowledge production and circulation (portability, accessibility, participation, data clouds, social networks, and collective intelligence) present in this environment signal a new socio-cultural paradigm for the social and natural sciences, and the humanities. The integration of digital technologies in archaeological practice, however, has not occurred in a homogeneous way. On the contrary, it provoked new debates and reiterated old ones (Torres, 2017, p. 11). While archaeologists from humanistic roots look suspiciously at how data is “dehumanized” when viewed and manipulated through a computer screen, proclaimed scientifically-oriented researchers emphasize the “objectifying properties” which results in more precision and accuracy through the use of digital techniques (Eiteljorg, 2004; Zubrow, 2006).

The relevance of this duality is well supported by the history of archaeological thought of the past 50 years, particularly in the paradigmatic clash established between the processual and post-processual schools of thought. Perhaps because Archaeology is a discipline in which ideas and methods from hard sciences, social and human sciences and aesthetics find an instigating environment, it is so permeable to the multiplicity of theoretical and methodological contributions that prevented the formation of a mainstream (Thomas, 2015: 11). In the quest to overcome this simplifying dichotomy, which is still rather prominent in our academic culture, some authors have emphasized the emergence of a new scenario, in which the integration between science and narrative, numbers and stories, is facilitated by the use of new information and communication technologies (Lock, 2003; Huggett, 2012a, 2012b).

This paper presents an overview of current discussions on the impact of standardizing systems of knowledge and on the importance of providing open access to primary data alongside and even prior to publication. We argue that presenting primary data in a standardized way is a prerequisite for the formulation of corroborative analysis, as well as complementary and alternative interpretations by researchers that were not originally involved in the primary data collection stage of any research project. Consistency in primary data presentation is also indispensable for comparisons that set the bases for the advancement of scientific disciplines.

The scientific process requires both a high degree of access to primary data and a certain degree of knowledge standardization to ensure a cross-cultural understanding of classifications, taxonomies, and vocabularies. This is especially true for nautical archaeology because its area of focus—shipbuilding and associated practices—is already a highly technical and specialized field, and contemporary vocabularies used to refer to ship parts were highly regional and changed through time. Because vessels are complex and multi-dimensional objects of study, and because they frequently sailed at extra-local (even global) scales, isolated research limits understanding and explanation. It is in light of this need that we have undertaken the creation of the Nautical Archaeology Digital Library (NADL)[1].

NADL was created in order to meet several needs: (a) to provide a platform for sharing primary data about maritime sites, (b) to create a standard for collecting information about shipwrecks, (c) to integrate data about shipwrecks, artefacts, and landscape features into a network structure that encourages comparative studies, (d) to facilitate communication among the international community of maritime archaeologists, and (e) to improve public awareness of the importance of maritime sites. Although not discussed in this paper, the platform also intends to create and share a glossary in several languages for historical terms of ship parts and to improve access to primary texts about and by shipwrights.

We acknowledge that sharing primary data prior to publication is a sensitive issue and that regularly an archaeologist alone cannot make the decisions on his or her own, especially if the research is executed within the Treaty of Valletta/Malta. Frequently archaeologists do not own the data and publishing them prior to publication tends to be problematic. Facing this reality, we believe a restricted period of an embargo on the data would help to solve the problem of largely researched data that take too long to be published or never gets published. It has to be kept in mind that publication and recognition are some of the most rewarding stages of archaeological work.

Publicly available information has played a major role in the development of science. There are many examples of how open-access scientific information has helped to enhance science. For example, the accelerated progress

[1] https://nadl.tamu.edu

of genetics in the last few decades owes much to the International Nucleotide Sequence Database Collaboration (INSDC)[2], which shares raw data between three partner organizations in Japan, Europe, and the United States.

In the same spirit, the Nautical Archaeology Digital Library (NADL) is intended to be a space where archaeologists from around the world can share information about our world's maritime history and exchange data with colleagues. Following the principles of open-access, we believe that the publication of raw data is necessary and significant. It allows other researchers the possibility to corroborate or challenge our hypotheses with novel approaches or additional data, or to build their own alternative and better-supported explanations. Much of what is collected during archaeological research will not end up in a publication as a result of that particular excavation. This data, however, may at later stage proof to become very useful for other scientists. The NADL will provide such a platform for data. Furthermore, open-access increases the availability of information for maritime archaeologists working in countries and areas with limited resources and/or less access to institutional support, a situation which is significantly more common than the converse.

In the following pages, we explain how scientific disciplines depend on the construction of common terminology, a process of systematization and primary data sharing. Later we will discuss different philosophical conceptions of science and how primary data, systematization and standardization lay in the centre of most scientific disciplines. Moving from abstract reasoning to more concrete problems, we address theoretical and methodological issues that on the one hand hinder the development of comprehensive explanations in nautical archaeology, but on the other are fundamental to the design and development of comparable templates. This project is an attempt to develop a common ground for the global community of maritime and underwater archaeologists, and we discuss the specific issues that arose in the process of creating standardized templates for projects and shipwrecks. To conclude, we reinforce the idea that the advance of archaeological science is enhanced by standardization and publication of information in open-source platforms.

2. General considerations on scientific knowledge, with a focus on archaeology

Disciplines are constituent fields of science, focused on generating knowledge by explaining, interpreting, and (hopefully) understanding certain parts or entities of the social and natural world. To gather and present this knowledge in an intelligible way, standardized procedures are used within the academic community to establish common ground. These procedures or methodologies derive from the paradigms and theoretical frameworks that define each field. Scientists propose explanations of reality based on a series of ontological, epistemological, axiological and methodological assumptions, always conforming to a generally accepted approach which is specific to each discipline (Sautu, 2005, pp. 27-28). Because multiple conceptual and theoretical approaches coexist, diverse methodologies compete within and between fields.

In the case of disciplines based on empirical facts, including archaeology, work consists of analyzing and offering answers to questions or problems using data collected from the available evidence (Klimovsky, 2005, pp. 21-25). John Stuart Mill (1806-1873) proposed an inductivist approach to scientific investigation, which consisted of a process of generalization based on the results of observations. However, he also supported that the complete verification of a hypothesis required the exclusion of all possible alternative hypotheses, which is regularly not the case in archaeology, where many conclusive contradictory narratives can be written about the same evidence (Mill, 2002).

George Berkeley's (1685-1753) and Ernst Mach (1838-1916) rejected the differentiation between "primary qualities" or objective characteristics of an object and "secondary qualities'' that are only present in the perceived experience of the subject (Berkeley, 1998). Mach (1959) went further to argue that appearance was the only achievable knowledge and that nothing could be known outside of the subjective understanding. It is true that the process of interpretation in archaeology is not ideology-free, but the recording process is largely based on pragmatic rules and supported by a wide range of scientific disciplines. We argue that certain characteristics of an archaeological artefact, including but not limited to its measurements and chemical composition, are objective qualities that exist independently from the observer and that is what we call primary data.

Instead, NADL adopts the perspective of Norman Campbell (1880-1949) and other post-WWII philosophers of science, who proposed that there is a hierarchy of levels in the language of science. At the base are the statements that contain the data collected using instruments, while the upper levels are composed of the theories and interpretations (Campbell, 2009). This hierarchy was taken into account when we generated the shipwreck template, which includes a variety of types of information. For example, it includes, listed in ascending order: measurements (base), long-form descriptions of hull components, typological categorization, and narrative interpretations of the ship's history (apex).

Karl Popper (1902-1994) asserted that the rules of the empiric method must be designed in such a way that they do not protect any scientific statement against falsifiability. Sharing primary data, which is one of the main goals of NADL, strictly follows this principle. Popper (1959) also suggested that if some data do not support a hypothesis, auxiliary hypotheses can be formulated to account for those data, but this auxiliary hypothesis have to enhance the potential falsifiability of the theory. "Popper observed the history of science is a sequence of conjectures, refutations, revised conjectures and new refutation and he concluded that the distinctive characteristic of scientific interpretations is to be susceptible to revision" (Losee, 1981, p. 181). Popper's thoughts closely align with the principles of primary data sharing and open-access, which increases the opportunities to falsify any interpretation by testing and enhances the possibility to formulate auxiliary and alternative hypotheses, forcing revisions of previous conjectures.

[2] http://www.insdc.org

In addition, we follow Percy W. Bridgman (1882-1961), as he recognized the importance of the intersubjective repeatability of scientific procedures, and the specification of the conditions under which each operation takes place (Losee, 1981, p. 183). We consider these two principles indispensable to our efforts at creating common ground through the standardization of primary data collection, a philosophy of sharing data early and often, and the search for a common methodological framework.

As we have seen, most philosophers of science agree that data, as empirically obtained information, are one of the two main components of science. An archaeological site is both a multidimensional jigsaw puzzle and a fragile archive that seldom allows archaeologists a second look. Excavating requires destroying a site whose true nature and boundaries are often unknown to the digger. While recording, the archaeologist will transform it into a different kind of archive that should contain a reconstructed context. Archaeologist Roger Hill (1994) proposed that the data are present in the ground, deposited there over time and by a range of dynamic processes that we often do not fully understand. The purpose of archaeological recording, Hill proposed, "is to transfer the ground-based record system into a form accessible not just to the site archaeologist, but to all potential users" (Hill, 1994, p. 141). It is our obligation to present data in such a way that it can be used by others. The way we can do this is by interpretation and, in fact, translation of the objective resource into something widely comprehensible and by finding a way to disseminate this to all potential users. In our age, this means a digital archive containing all information considered relevant to its interpretation. This new archive can only be developed with the knowledge and by using the technology available to the archaeological teams, a set of constraints that is always evolving. Most countries have published sets of common rules and methods for excavating, recording and presenting archaeological data. This is the only way to ensure *intersubjective repeatability*. However, usually, this is–at best–nationally and not globally determined. If we want to transfer the archaeological record into a form that is accessible for other people beyond the site archaeologist, a common language in maritime, nautical and underwater archaeology needs to be developed.

3. A common language: terminology and systematization

Language is the channel of communication. Scientists employ precise vocabularies—terminologies—to refer to entities and concepts. A terminology consists of a set or system of specific terms that denominate and designate the objects to which they are applied (Vidal Torres Caballero, 1994, p. 85). Because of this, it is not just a means of communication, but a means of conceptualizing the reality that is under study.

Each discipline or speciality defines and implements a terminology that is developed in accordance with a particular structuration and interpretation of reality (Coseriu, 1977, p. 96). Given the multiplicity of theoretical approaches and to the different *language-games* (*sensu* Wittgenstein, 2006), a single term usually encompasses different meanings, or put another way, it has different designation fields. In some disciplines, *divergent thinking* is common, making the definition of terms more complex (see Kuhn, 1977, among others). This is especially true when disciplines and/or specialities with different trajectories interact, for instance in multidisciplinary and interdisciplinary approaches. Such approaches are inherent to archaeology because the field interprets such a wide variety of types of information obtained from structures, artefacts, and other types of remains, with methods and techniques often borrowed from other scientific disciplines.

The systematization of terms, concepts, and analytical strategies becomes particularly important when the goal is to solve a common problem such as describing shipwrecks. However, the elements of the systemization process are not static. Menéndez stated that concepts are instruments created around particular problems, and as such, they are subjected to changes (and sometimes even acquire a polysemic character or a plurality of meanings) due to theoretical resignifications and the practice of science itself (Menéndez, 1999, p. 155).

This means that despite the fact that the intelligibility of the discourse is very important, the concepts used in the social sciences cannot be defined in a strict sense (fulfilling the conditions of necessity and sufficiency) or be closed or static as proposed by Frege (1903). Accordingly, concepts used in archaeology tend to have a non-definitive or open character (Weitz, 1977, p. 19). Therefore, to avoid misunderstandings, agreement on fundamental aspects is required.

Among the philosophers of science, Ernest Nagel (1901-1985) was a strong advocate of standardization. He argued that the formalization of disciplines was necessary and that for each discipline, the meaning of the terms used in theories must be fixed by rules defining their appropriate use (Nagel, 1961).

Despite its necessity, archaeologists must consider that the process of standardization is potentially reductive. Trying to organize taxonomies and cladistics of collections and data requires the comparative analysis of information with disparate formats and presentations. Even before considering regional and individual differences between archaeological teams and their methodologies, shipwrecks, maritime landscapes, submerged structures and artefacts from maritime sites each have different relevant features, exist on different scales (e.g., size or geographic distribution), and require different methodologies for recording and analysis.

Whether archaeologists should standardize the way in which they present information has been a subject of debate in the field (Eerkens & Bettinger, 2001; Huggett, 2012a, 2012b; Shanks & McGuire, 1996). It is true that standardization limits an infinite scope of possibilities to record, to present, and to interpret a given archaeological object or complex, and this subject is especially contentious if the person involved does not consider archaeology a science or understands science from a non-orthodox perspective following the ideas of philosophers such as Paul Feyerabend (1924-1994), Nelson Goodman (1906-1998) or Stephen Toulmin (1922-2009). It may even limit innovations in methodological and technical approaches. However, our first argument is that describing an object–such as a molecule, a cell, an insect, or a ship–in a standardized way does not preclude the development of additional, standard-free narratives. Moreover, a certain degree of consistency in the presentation of the data is necessary to allow comparisons and, in our case, to fulfil the requirements of a successful web page intended for international use (Castro et al., 2018). It is therefore important to limit the standardization to crucial components that are likely to be compared and collected, such as–among others–positions, date, size (of specific elements), the function of the ship and metadata of the collected data.

The NADL already encompasses contributions of scholars from more than forty-four different countries, and all the continents are represented. The growing number of contributors and their diverse cultural and academic backgrounds has caused an increasing flow of information that requires an effort towards organization and standardization.

In the NADL case (as part of structuring the knowledge for socialization) the use of a unified system to record shipwrecks and research projects will allow us to simultaneously achieve two central purposes of the research practice: the straightforward communication of primary data and research outcomes among scholars, and the dissemination of scientific advances to the general public. This scheme by no means excludes other proposals that follow the ethical guidelines of archaeology, nor does it imply that other, parallel descriptions–both of the sites as found, and of the site formation processes–should be discouraged.

In the following section, we will discuss the complexity of shipwrecks as objects of study, and how these can affect our understanding and interpretation of sites. In addition, we identify certain barriers to widespread collaboration and comparative analysis. As in other fields of study, we argue that isolation is detrimental and that the development of open-access templates facilitates comparisons and interpretation, thus contributing to the development of science and to overcome the aforementioned barriers.

4. Shipwrecks as complex artefacts: the need for widely-available bases for comparison

Vessels are complex objects to study because they are involved, both temporally and spatially, in complex dynamics during their lifetime and after they become objects of study. They are conceived before they are built (Pomey, 2011) and multiple constraints, both physical and metaphysical, affect their production (Adams, 2001, p. 300). They carry both people and goods. They suffer multiple changes and play different roles during their life-span. Eventually, they are lost, abandoned or recycled, and then subsequently become archaeological sites which are excavated, recorded, interpreted and published. Their mobility means they are sailed through different parts of the world, in many cases transcending local and regional spheres. Their physical structures and everything they carry come from distinct and often multiple temporal and spatial spheres. Shipwrecks are also subject to transformation and change even after their sinking, which itself frequently takes place far from their homeland. This is especially true for the period in which the expansion of capitalism led to an intensification of worldwide sailing, global commerce, and the wide circulation of raw materials and manufactured goods.

Understanding the complexity of such objects requires observing their multi-layered nature. Following Bailey's view on time perspectivism, 'different phenomena operate over different time spans and at different temporal resolutions' and thus 'different sorts of phenomena are best studied at different time scales' (Bailey, 2007, pp. 201-202). The author also bears in mind how perspective–both regarding scale and positioning–distorts our perception of reality, and how subjectivity (cognitive, symbolic, cultural and social dispositions) impacts on how we think about time. These same aspects can be considered regarding space. Several authors have considered the effect of observation at multiple spatial scales on explanation (Ford, 2011; Locke & Molyneux, 2006; Westerdahl, 1992).

In his work, Bailey describes shipwrecks as *temporal* palimpsests, a concept which, as we will see, is applied mainly to single-episode depositional contexts. However, as Adams (2001, p. 296) states, "the wrecking locates, in time and space, all constituent materials of the vessel and its contents in the context of that event, but it does not follow that they were all in use at the same time or are associated by uniformly strong relationships". Bailey's own notions on time perspectivism and scale of the analysis challenge the conception of shipwrecks as isolated events. We argue that the scale and scope of the information they can provide depends greatly on the standpoint, the perspective and the aim of the researcher, and thus shipwrecks are potentially also *spatial*, *true*, *cumulative*, and *meaningful* palimpsests (Bailey, 2007).

A *temporal* palimpsest is 'an assemblage of materials and objects that form part of the same deposit but are of different ages and 'life' spans' (Bailey 2007: 207). This can be seen even in sites where the materials are all part of the same activity or singular episode. Even if we can hardly regard shipwrecks as 'closed finds', we do understand that vessels contain, and are composed of, a multiplicity of materials. Their structures and constituent parts (fasteners, timbers, caulking, paint, sails, etc.), their cargo, ordinance, personal belongings, equipment and so on. Each one has its own biography, not only through time, but also through space.

We argue, then, that shipwrecks are also *spatial* palimpsests. Their own mobility and their accumulation of materials from varying provenances mean that throughout their lifetime they are involved in spatially distinct activities, and this can bias both their understanding and interpretation. But what happens after the shipwreck can also obscure the full picture: the site formation processes; the circumstances surrounding the discovery; the excavation process; the relocation of artefacts for conservation, storage, and museum displays; the research conducted; the dissemination of information; and the political and cultural contexts in which they exist all affect the final conclusions made by researchers. Chemical, biological and physical deterioration operate differently in different water bodies. In addition, the logistics of the excavation (such as its overall scale) can be affected by sedimentary contexts and dive conditions, including depth, temperatures, visibility, wind and water dynamics.

Cultural transformations (Muckelroy, 1976, 1978; Shiffer, 1987) also operate in particular ways in different sites. Some vessels are more thoroughly excavated than others; some are better preserved due to their geographic area or period; some are studied but never published. Sometimes, there is greater interest in specific time-periods or ships due to, for example, preservation risks or historical significance, creating differentials in funding opportunities or political support. Following Bailey, wide-scale differences in preservation or recovery of information also create a spatial palimpsest, but at a greater geographical scale than at the site level. This is true for every archaeological context, but the mobility of vessels turns spatial considerations into a fundamental aspect of our understanding of maritime and nautical dynamics.

As *true* palimpsests, ships comprise sequences "of depositional episodes in which successive layers of activity are superimposed on preceding ones in such a way as to remove all or most of the evidence of the preceding activity" (Bailey, 2007, p. 204). When a ship is repaired or transformed, materials are removed from the original structure and replaced by new ones. We can frequently recognize the changes, but the original evidence may be lost forever. That is why recording absences is as important as recording presences. As in the cases of repair and transformation, events such as commerce, loading and unloading imply loss and the subsequent renewal of cargos. Some events, however, can also become *cumulative* palimpsests, where there is no loss of evidence, but the superimposed episodes of deposition are impossible to distinguish into original constituents because they are mixed together and re-worked. Commerce and circulation through different harbours can also generate this type of palimpsest within vessels, loaded with a variety of objects and personal belongings, which in turn may have been transported from their places of origin to connecting harbours (Nieto Prieto, 1997). The adjustment of ballast and the constant buildup of waste in the bilge can also become *cumulative* palimpsests.

Furthermore, vessels themselves experience their own biographical history (Schiffer, 1972, 1987). They can be repurposed for a new function, either for sailing or museum display, or they can transform into shipwrecks, which are surveyed, studied and excavated. They thus become palimpsests of *meaning*, as they condense a succession of meanings acquired as a result of different uses, contexts of use and associations, which can also be symbolic. Subjectivity has the greatest impact on this kind of palimpsest.

The consideration of the multi-layered nature of vessels is paramount. There is no greater limitation for a deeper understanding of our object of study than spatial and temporal biases. Overcoming them means not only transcending singular descriptions and interpretations, but also connecting shipwrecks to each other and to the wider socio-cultural processes that affected them and that they, in turn, played a part in. The explanatory potential of shipwreck sites for archaeology as a whole can be significantly enhanced by closer study not just of the multiple temporal and spatial layers that exist within them, but also what occurred far beyond the bodies of water in which ships operated. To accomplish this, we must connect the research being conducted worldwide. Although we focus here on connecting shipwreck data all over the world, we also strongly feel that this should not stop there, but that shipwreck data should connect with other maritime data: that of landscapes and seascapes for example. Finally, we sincerely hope that maritime–including shipwreck–data will be more regularly used in general archaeological and historical interpretations, because, in the end, it is all about the interpretation of the past that can be looked upon and researched from different angles.

Biases do not only involve the nature of the object of study. They also occur in the dissemination of information about each of these stages: the ship; its conception, construction, sailing life, and demise; site formation processes; and excavating, recording, interpreting its place in the larger (global) context and publishing the site. Even if international journals aim to tackle the biases, language barriers and infrastructure problems, it remains a fact that high-standard research does not always reach wider dissemination levels. This is also the case with scientific meetings.

NADL hopes that by providing free access to raw data, creating networks between researchers, sharing documents and other resources, and establishing a worldwide forum, we can expand the bases for the comparisons on which archaeological and anthropological explanations are founded. In doing so, we will be able to develop more comprehensive explanations, as proposed by Popper (1959). This offers new possibilities and perspectives for archaeological research. It will help integrate information from wide areas and chronologies, and make the best of the objects we study. Comprehensive research can shed light on topics such as the history of technology, shipbuilding, commerce, and environmental adaptations, and can enrich our knowledge of wide-scale networks (of goods, information, technology and symbolic interactions).

Although we cannot ignore the complexity inherent in shipwrecks, in order to facilitate dialogue and comparison, we must establish a common language and standardized parameters for collecting information on and describing wrecks.

5. Seeking a common ground

"Standardization is as old as interactions within larger human communities. The first Chinese emperor, Qin Shi Huang (260 to 210 BC), standardized not only the Chinese characters, but also the system of units and measurements as well as the currency and the width of cart axles" (Zeltwanger, 2015).

Controlled vocabularies define the scope of terms and oftentimes provide synonyms to help to reduce ambiguity (Tudhope et al., 2011). Complex Knowledge Organization Systems (KOC), also known as formal ontologies, establish semantic relationships that organize concepts and improve the choices of terminology, representations and information structures that connect people and machines.

One such tool, the CIDOC Conceptual Reference Model (CRM)[3], is a theoretical and practical tool for information integration in the field of cultural heritage. It helps researchers, administrators and the public explore complex questions. By providing definitions of and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation, it enables people to query diverse and dispersed datasets in a software and schema-agnostic fashion (Doerr et al., 2020). Although NADL has not reached this point yet, one of the goals is to generate an ontology that improves intercultural terminology, intelligibility and compatibility, as the British Projects STAR (Semantic Technologies for Archaeological Resources) and STELLAR (Semantic Technologies

[3] http://www.cidoc-crm.org

Enhancing Links and Linked data for Resources). So far, NADL contributors have developed two templates: a project template and a shipwreck template to make easier the semantic interoperability among different maritime archaeology data sets produced by different institutions and scholars from around the world.

The templates enhance the display of information by creating a standardized and responsive web page. They also allow quantitative and qualitative comparisons by collecting consistent information for each wreck. Additionally, they create an advanced search function that serves as a tool for intra-site cross-searching by assigning each topic (kind of artefact) its own place, while it is still displayed as a component of the broader picture (shipwreck site or archaeological project). Most importantly, they generate a common ground for international cooperation to set the minimum recording standards for maritime archaeology projects.

As most archaeologists are not programmers or web designers, data entry is done through digital forms hosted on the site. The site then displays the information entered in the forms in a standardized format. In addition, a simple version of the most important fields for the template was created as an XSL spreadsheet to allow the bulk upload of many sites. This template is accompanied by a set of instructions for how to format the data to allow the computer to read it properly.

These attempts towards standardization will eventually allow the users to display together and compare information that previously seemed disconnected or incompatible. For example, it will allow qualitative comparisons between rigging elements across time, for the reconstruction of their development, while simultaneously allowing the synchronous comparison of all rigging elements from the same period. Additionally, it will allow comparisons of quantitative attributes, such as measurements like keel-to-beam ratios, tonnage, or the length, sided and moulded dimensions of specific timbers.

One important feature built into this template is the automatic generation of a spreadsheet compatible with the Maritime Stepping Stones (MaSS) website[4], a scholarly online database of shipwrecks maintained by the Cultural Agency of the Netherlands (RCE) with which NADL is partnering. Through an open-access viewer, MaSS can be searched by anybody for example on name, area and period. The aim is multiple: the system shows the richness of the underwater cultural heritage as a historical resource and it serves as a publicly available and attractively looking data source for anybody in need of information about our (common) maritime history. MaSS was originally developed from Wrecks in Situ (WIS) as part of the European scientific project Managing Cultural Heritage Underwater (MACHU), alongside a Geographic Information System MACHU, which is a password protected collaboration between the Netherlands ministries of Education, Culture and Science, Transport and Water Management and Defense (Manders, Oosting & Brouwers, 2009). Both systems are being actively used but have considerably developed over time[5]. MACHU-GIS was one of the first to comply with the INSPIRE[6] regulations, since both were developed at the same time, were EU projects and kept in contact about any developments in European Union spatial data infrastructure. INSPIRE deals with data specifications or standards to promote the exchange of them within the European Union.

6. The shipwreck template

Our template desig–which we intend to be a work in permanent progress–required finding the balance between the necessity of capturing the individuality of specific ships and boats (remaining sensitive to the smallest variations in style, taste, technical skills, symbolic values, etc.) and the necessity of developing a dataset that allows for comparative studies. As we have mentioned above, the process of standardizing the description of any complex structure is an abstract endeavour that requires both interpretation and simplification of the object described. Again, it is a fact that despite the problems inherent to simplification, biologists have established a process for describing life forms based on matrices of traits that have proven functional enough to allow for comparative studies.

In the field of nautical archaeology, J. Richard Steffy already saw the research potential of standardizing descriptions of boat and ship's hulls' remains in the 1980s. The development of computers–particularly at the Texas A&M University College Station campus where Steffy was offered a teaching position in 1976–inspired him to develop a scientific process for recording, comparing, and studying ship archaeological remains. For that, he was awarded a MacArthur Foundation Fellowship in 1985.

Computers were promising tools for the study of shipbuilding in the 1980s. Comparative studies seemed to J. Richard Steffy like a natural way to understand shipbuilding as a particular type of human behaviour. The first step was naturally inventorying and comparing construction features and he threw himself at the problem. By the late 1990s, he had developed a database containing 13 large spreadsheets, which detailed construction features and scantlings, and related the data to the chronological and geographic environments where each ship and boat was built and sailed (Steffy, 1995; Castro et al., 2018).

Three decades later, the tools available off the shelf for the inventory of shipwrecks are comparatively cheaper and more powerful, but we still do not have a standard for the recording of ships and boats. Steffy (1990) wrote:

> We must admit to an unbridled confusion in the recording and publication of our vessels. Of the forty-four subjects considered for this study [his database], little more than half of them have been reported formally. Of the eighteen categories I chose for comparison, only a few wrecks filled all of the columns, even though the information must have been available on many others. I am not criticizing the way in which anyone documents their shipwrecks, because we have differing priorities and varying opinions about what is and what is not important. But I do think that in the future we must take a clue

[4] https://mass.cultureelerfgoed.nl

[5] https://english.cultureelerfgoed.nl/topics/maritime-heritage/data-on-underwater-cultural-heritage

[6] https://inspire.ec.europa.eu/about-inspire/563

from the older artifact disciplines and all record the same basic features where they survive.

It is our hope that this site will serve as a step towards this goal.

The NADL templates aim to take Steffy's goals a step further. The template designed to enter shipwrecks into our public database is therefore simple, but at the same time attempts to be as comprehensive as possible, having in mind that the purpose of the website is not to replace the peer-reviewed publications, but being an as-complete-as-possible inventory of known shipwreck sites.

7. Implementation

The site was built in WordPress, a highly flexible open-source platform that was originally built for blogging but has evolved to support far more complex websites. A paid plugin called *Toolset* handles the database-type functionality for the site. Toolset allows the creation of custom post types with custom fields, their categorization using custom taxonomy terms, and the formation of relationships between them. All relationship types (one-to-one, one-to-many, and many-to-many) are supported. Toolset also allows the creation of front-end forms for submitting data, as well as the creation of custom search engines and archive pages for querying the database. Although this plugin also allows the creation of templates for displaying the data by using WordPress' default block editor, we chose to use the page builder *Elementor Pro* with the addon *Dynamic Content for Elementor* by *Dynamic.ooo*, to facilitate this process. Interfacing between *Toolset* and *Elementor/Dynamic Content* required some custom PHP code.

7.1. NADL Template Basic Structure

We have based the structure of the template in the seven simple principles proposed in a 2018 paper about Richard Steffy's work and the necessity of agreeing on a standard methodology to describe shipwrecks (Castro et al., 2018), with appropriate modifications. The sections are as follows:

1. Ship History
2. Ship's Contents
3. Excavation and Research
4. Hull Analysis
5. Outfitting and Rigging
6. References

7.1.1. Database structure

Shipwrecks form the centre of the database structure (Fig. 1). Using Toolset, we created a custom post type called Shipwreck, which functions as an object in the site's MySQL database. Three additional custom post types–(1) Ship Contents, (2) Hull Analysis, and (3) Outfitting and Rigging Analysis–were also created and assigned to Shipwrecks as child posts in a one-to-one relationship. These child posts allowed us space to provide more technical information (of interest to chiefly to domain experts) and longer descriptions (such as the list of ship contents), separate from the more general information (of interest to the general public) without overwhelming the layout of the main Shipwreck template.

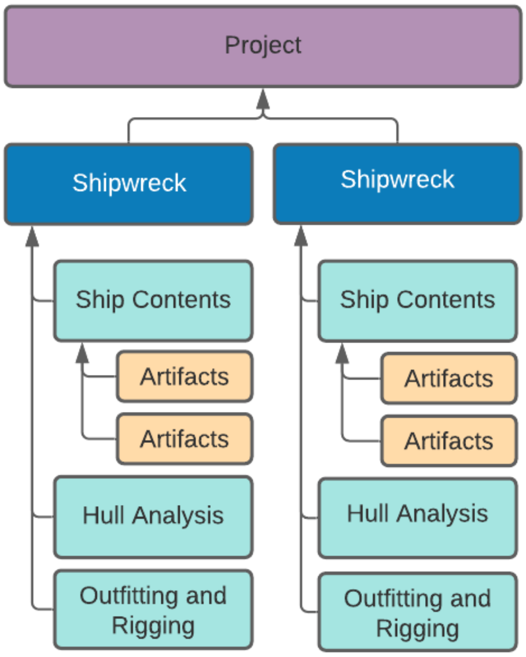

Figure 1: Database structure.

The fields used to describe the shipwrecks were each assigned to one of the four-post types. The Elementor templates that display each post type can pull information from the child and parent posts through the post-relationship (set using Toolset). For example, the shipwreck name, dates, and overview (excerpt) is displayed on each of the child posts without needing to be entered a second time.

In the future, two new types of database objects (post types) will be added: (1) Projects and (2) Artefacts. Projects will be used to create relationships between shipwrecks, so that multiple shipwrecks can be assigned to the same project or multiple projects can be assigned to one shipwreck (many-to-many relationships).

Artefacts will be assigned to Ship Contents (one-to-many), so that site visitors can see a list of artefacts found in each shipwreck. Artefacts will also be categorized by artefact type, so that artefacts found on different shipwrecks can be compared.

7.1.2. Site Structure

A description of the fields assigned to each custom post type can be found in Table 1. These fields are filled using front-end forms, and stored as metadata for each custom post type in the sites MySQL database. In order to improve the user's experience when viewing the site, only the fields that have data entered in them are visible.

This template should permit the contributors to enter enough information to characterize a shipwreck site, and to organize the data to facilitate comparative studies.

A custom search page allows visitors to query the database to identify wrecks with certain characteristics. Visitors can search by any one or multiple of the following criteria:

- By time:
  - Choosing a period from a drop-down menu.
  - Entering minimum and maximum year built or year fate (e.g., sank).

Table 1: Descriptions of main and secondary pages for each content area.

Content area	*Main Page*	*Secondary Pages*
1. Ship History	• A tentative interpretation of the site: identification, typology, origin, reconstruction image (if available), where built (if known), and any known information about the ship's history. • Basic dimensions: length, breadth, depth, tonnage, total guns, and gun types.	
2. Ship's Contents	• Overview and a general image of the site showing contents.	• Detailed dimensions of the cargo area. • Descriptions of contents by category: human remains, shipboard life, cargo, weapons, stores, faunal and botanical remains, ballast, and unidentified artefacts.
3. Excavation and Research	• Research institution and primary investigators. • Site location and detailed description. • Status of the site (jurisdiction and current status).	
4. Hull Analysis	• Categorization of hull (hull type and construction type). • Reconstruction image and reconstructed dimensions. • Description of hull remains. • Hull map.	• All information above. • Images. • Hull analysis, including repairs, material analysis, fasteners, and sheathing. • Scantling list and timber descriptions.
5. Outfitting and Rigging	• Categorization and description of each type of propulsion (wind power, human power, mechanical/engine power). • Anchors for sites comprised of isolated anchors.	• All information above. • Description of rigging elements. • Description and dimensions of anchors. • Ship's gear (steering, pumps, and winches).
6. References	• All references.	• Each secondary page can also include a list of additional references specific to the topic.

- By place of origin or site location:
  - Choosing a region from a drop-down menu.
  - Entering minimum and maximum latitude and longitude variables.
- By area of operation:
  - Choosing a region from a drop-down menu.
- By ship type:
  - Choosing a ship type from a drop-down menu.
  - Entering a minimum and maximum number of guns.
  - Choosing an owner/operator from a drop-down menu (e.g., British Royal Navy or Dutch East India Company).
- By dimensions:
  - Entering minimum and maximum tonnage, length, breadth, or depth.

In addition, shipwreck entries can be assigned to different research institutions, which will enable the creation of pages listing research conducted at different places, including shipwreck excavations, graduate student work, and projects on any scale from artefact to landscape studies.

In the future, we hope to add the ability to do side-by-side comparisons and/or to present graphs aggregated from all shipwrecks in the database, such a graph showing changes in ship dimensions over time.

7.2. Open vs. closed sections

For each field containing data, decisions had to be made on whether to prioritize standardizing data or collecting the maximum amount of information. In former sections, we spoke about different concepts of data proposed by philosophers of science. These axiomatic systems of empirically obtained information are the basis for any study, which in the case of archaeology can be approached from many different theoretical perspectives. We choose to follow Campbell (2009), who identifies a hierarchy of information, depending on how much interpretation has been applied to it.

While direct measurements of ship parts (the base of the hierarchy) were an obvious choice to include, not all relevant information can be expressed as a single measurement. For some types of information, published taxonomies provide clear ways to categorize ships, such as by shell-first, skeleton-first or bottom-based construction. Although such taxonomies are interpretative (higher on the hierarchy), they are also simple to create from a technical standpoint, because they are closed (there is a finite number of choices to program for). For other types of information, either there is no categorization, the possible taxonomies are disputed, or reducing the field to a taxonomy requires leaving out potentially highly significant information. For example, it is not enough to categorize the markings present on wood, which often provide key information about the conceptualization and building of a ship, as "present" or "absent." Nor is it possible to categorize all possible markings made on all shipwrecks through time into a simple set of multiple-choice options. The complexity of shipwreck sites, which are simultaneously *temporal*, *spatial*, *true*, *cumulative*, and *meaningful* palimpsests, makes them difficult to accurately capture using only closed fields.

We chose to balance these needs by creating both standardized fields to capture essential information (closed fields) and WYSIWYG (What You See Is What You Get) fields where additional information can be entered in paragraph form (open fields). Furthermore, the use of repeatable fields and repeatable field groups allows flexibility where needed, such as when entering timbers and masts (the names for which change over time and between places). A few examples will serve to illustrate the process of creating the template.

7.2.1. Year

While it is objectively true that the shipwreck sunk at a certain date and time, our ability to date a site is not always that precise: we might know the exact day it was launched and the exact time it sank or we might only be able to date it to within a range as broad as several centuries. On the other hand, it was necessary to keep the format of information standard between wrecks in order to build the template. Ultimately, we created two number fields, one that could contain either the year built or the *terminus post quem* and one for either the year fate or *terminus ante quem*. This allows the entry of exact years, if known, such as 1776-1781, or a range, such as 800-1000 CE. To give another example, if a site is dated to the late 14th century, this can be entered as 1375-1400. Both dates are then displayed with the date on the website (Figure 2). In addition, the person entering the data is asked to choose a description of the precision of the date from the following options:

- Exact (known from records).
- Measured (known from dating methods).
- Estimated (approximated from features or cargo).
- Unknown (method of dating unknown).

7.2.2. Ship Contents

Because of the diversity of artefacts that can be found on ships, this section was broken down into sections, but each section includes only a description field (WSIWYG) and a place to add images. Eventually, it will be possible to create specific artefacts as separate objects in the database (and in turn categorized by type and other significant features) and assign them to the shipwreck. The following fields were used:

- Overview.
- Human Remains.
- Shipboard Life:
  - Personal Possessions.
  - Clothing and Uniforms.
  - Spirituality, Leisure.
  - Health and Hygiene.
  - Shipboard Tools.
  - Furniture.
  - Coins, Bullion, and Valuables.
- Cargo.

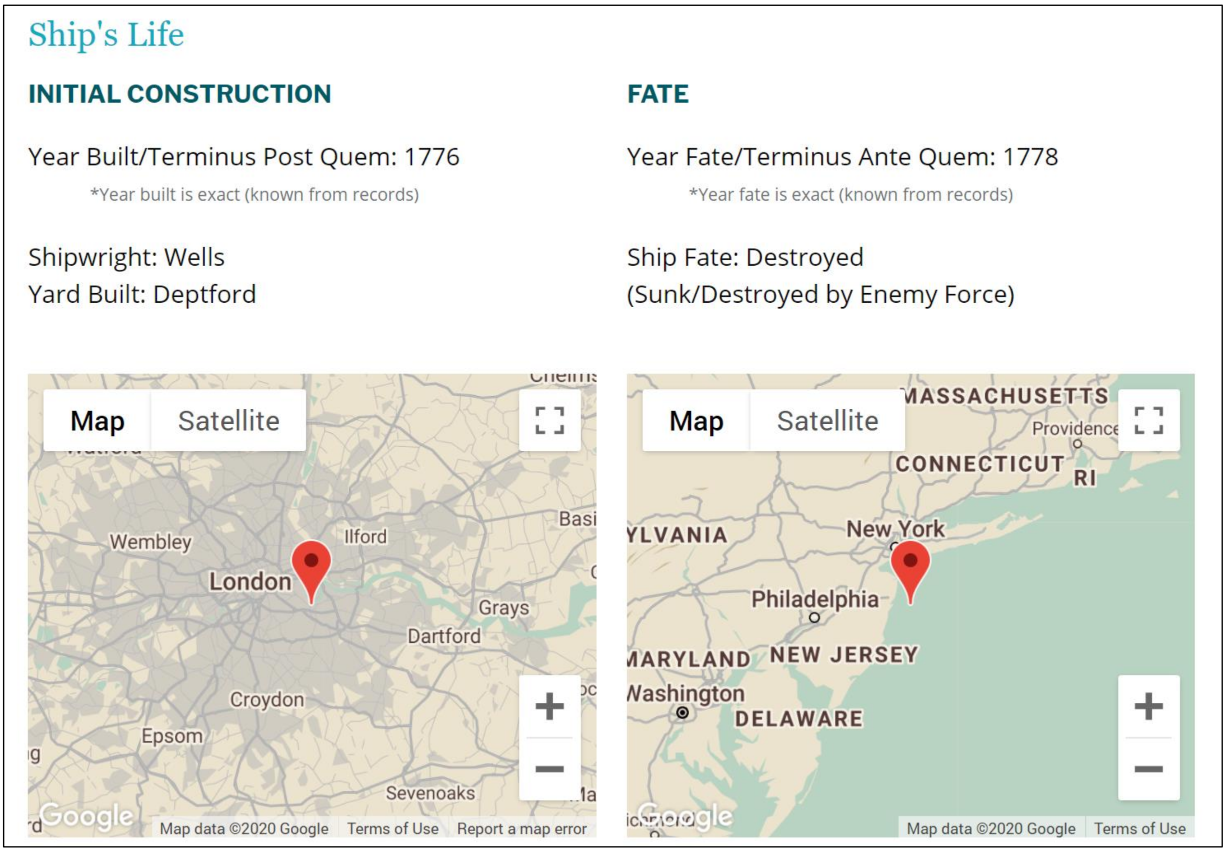

Figure 2: Display of year built and year fate in the Ship History Section.

- Weapons:
  - Ordinance.
  - Small Arms and Personal Weapons.
- Stores.
- Faunal and Botanical Remains.
- Ballast.
- Other and Unidentified.

7.2.3. Timbers

For all shipwrecks, information on the following timbers is collected. All timbers include fields for length, sided, and moulded dimensions; the material they are made from (both general–e.g., hardwood–and specific–e.g., oak); a description field; a field for describing markings; and a field for images. For stems, sternposts, and frames, a few additional fields (below) are also included by default:

- Keel (and Keelson)
- Stem:
  - Shape (convex, straight, or concave).
  - Rake angle.
- Sternpost:
  - Shape (convex, straight, or concave).
  - Assembly type (e.g., transom).
  - Rake angle.
- Frames:
  - Frame Type (e.g., V-shaped or Canted).
  - Futtock Types (e.g., 'overlapping unfastened' or 'filled–no gaps/room and space').
- Planking.

Using a repeatable field group, as many additional timbers as needed can be added. The timber can then be named, and the following fields entered: dimensions, material, description, markings, and images. In addition, two "blank" fields are provided which can themselves be named. For example, a new timber field group could be added for the mast step, and the dimensions and description added. In addition, one of the blank fields could be used to categorize the mast step by typology.

7.2.4. Anchors

Multiple anchors can also be added to a single site. For each anchor added, one of four types is chosen, with the dimensions named appropriately. Checkboxes are used for assigning material types, so that composite anchors, such as lead and wood anchors, can be indicated. In addition, for stocked anchors, a typology of shapes is entered.

- Stone:
  - Material(s).
  - Dimensions (Height, Width, Thickness).
- Stocked:
  - Material(s).
  - Shape.
  - Dimensions (Shank length, Stock length, Arm length).
- Stockless:
  - Material(s).
  - Dimensions (Shank length, Stock length, Arm length).
- Other:
  - Material(s).
  - Dimensions (Height, Width, Thickness).

There is a setting to display the anchor on the main page, rather than only on the secondary page, to accommodate sites that are composed of an isolated anchor with no associated shipwreck.

7.3. Categorizing shipwrecks

In order to facilitate comparative studies, we wanted to be able to list the same shipwreck in multiple places, such as by both time period and region built. Shipwrecks were assigned to the following taxonomies:

- Time Periods:
  - Time periods were subdivided by region, as the categories that are useful in describing European history are not necessarily relevant elsewhere, such as Asia. Even within a region, some periods overlap, such as the Viking Age and the Middle Ages. Even year-numbering can vary considerably. For example, there are differences in the way the western world and the Thai culture calculate the years. If such is the case, both dates should be included.
- Ship Types:
  - Broadly divided into Merchant, Naval, Whaler/ Fishing, Exploratory/Science, Small Craft (e.g., canoes), Work ship (e.g., dredge, inspection, transport), Other and Unknown, with specific ship types for each subcategory. Different researchers might need to expand this typology to account for their own viewpoints and applications, as for example, if slave ships are in a category of their own, instead of being aggregated into the merchant ships group. It has to be kept in mind that ships might have had more than one function. If such is the case, it is possible to assign it to more than one ship type.
- Owners/Operators:
  - Includes both individual navies and merchant companies such as the East India companies.
- Areas of Operation:
  - Includes both specific trade routes and theatres of war.
- Places of Origin:
  - Divided by continent and then by region.
- Site Locations:
  - Divided by continent and then by the body of water, as well as by the current country and more specific location.

As with all digital projects, we expect ours to evolve, improve, and expand in the future. As it is, however, it stands as a fair and implementable attempt to standardize the study of shipbuilding through time.

8. Conclusions

The NADL primary idea was the development of a set of tools to: (a) provide a platform for sharing primary data about maritime sites, (b) create a standard for collecting information about shipwrecks, (c) integrate data about shipwrecks, artefacts, and landscape features into a network structure that encourages comparative studies, (d) facilitate communication among the international community of maritime archaeologists, and (e) improve public awareness of the importance of maritime sites.

In order to facilitate communication among the international community of maritime archaeologists we are working to develop ways to more efficiently catalogue, store, and manage artefacts and ship remains, along with the associated data and information produced by underwater archaeological research. We also want to integrate heterogeneous data sources from different media, in order to facilitate research work and handle uncertainty in data and structure, and to incorporate historic sources that help in the study of artefacts. We are looking at ways to develop visualization tools, to help researchers manipulate, observe, study, and analyze artefacts and their relationships. Finally, we are trying to develop visualization tools to share our scholarly work to an as wide as possible audience.

It is paramount that researchers find the data they are looking for easily, and that entails developing a careful methodology to assign metadata to each unit of information stored. We also argue that it is extremely important that the primary data and their interpretations can be stored and consulted separately at all times: the academic community should be able to see how data were recovered and stored, account for the uncertainty of all archaeological data, and document its origins and limitations. We should be able to trace how scientists discuss the data and use them for interpretation; this constitutes the subjective part of our profession. If we follow this guideline, conclusions and interpretations can be checked, tested, and discussed without having to doubt or to guess about the primary data on which the interpretations are based and the conclusions are formulated. Since this is a developing project, based on community participation, we expect the users' feedback to help us refine the data taxonomy to reflect diversity and inclusivity in the data. These goals require a balance of standardization and flexibility in order to share primary data per the principle of open-access in a way that is coherent and intelligible to a wide community of domain experts with different cultural and academic backgrounds.

When this project started, in 2006, funded by an NSF grant (IIS-0534314), we developed the planned computer tools and optimistically relied on colleagues–domain experts–to help us populate the digital tools with data (Furuta et al., 2007a, 2007b; Monroy et al., 2006, 2007, 2009, 2010). We soon, however, found out that time is a rare resource in academia and that we needed a much larger pool of experts if we wanted to create content in our digital library.

More than a decade later we are a team of over one hundred collaborators from over forty countries, and we managed to create a community dedicated to producing content and providing network opportunities to the younger generations of nautical, maritime and underwater archaeologists. We are building into this project the tools that will hopefully allow it to stay open to change and improve, as well as maintain a balance between the necessity of defining our study objects and furthering knowledge related to these topics.

As we have shown, scientific knowledge is affected by the complexity of the objects we are trying to describe as well as natural cultural biases of the diverse community of experts we are trying to create. Nonetheless, standardization is still an important and necessary goal, as is maintaining sufficient flexibility to meet the demands and questions determined by the ever-changing state of the field.

The development of a template capable of describing any shipwreck was an iterative process, developed slowly and with the input of a diverse team of scholars. The inclusion of metadata that categorizes the shipwrecks in multiple ways ensures the information captured is of ready use to those who need it. We hope it will continue to evolve and in time allow wide and free access to (at least) the most important shipwrecks found so far, and that it will facilitate comparative studies that advance the field as a whole. Further efforts will be oriented towards the creation of an ontology, to ensure the intelligibility and compatibility of intercultural and diachronic terminology. As NADL is a work in progress, changes will be made to improve and adapt the database to a growing community of users of different cultural backgrounds and scientific needs. We encourage maritime archaeologists to contact us with comments and suggestions, as well as to join this global effort towards the research, protection and outreach of underwater cultural heritage.

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References

Adams, J. (2001). Ships and boats as archaeological source material. *World Archaeology*, *32*(3), 292–310. https://doi.org/10.1080/00438240120048644

Bailey, G. (2007). Time perspectives, palimpsests, and the archaeology of time. *Journal of Anthropological Archaeology*, *26*(2), 198–223. https://doi.org/10.1016/j.jaa.2006.08.002

Berkeley, G. (1998). *A Treatise Concerning the Principles of Human Knowledge*. Oxford University Press.

Campbell, R. N. (2009). *What is Science?* London: Cornell University Library.

Castro, F., Bendig, C., Bérubé, M., Borrero, R., Budsberg, N., Dostal, C., Monteiro, A., Smith, C., Torres, R., & Yamafune, K. (2018). Recording, publishing, and reconstructing wooden shipwrecks. *Journal of Maritime Archaeology*, *13*(1), 55–66. https://doi.org/10.1007/s11457-017-9185-8

Coseriu, E. (1977). *Principios de semántica estructural*. Madrid: Gredos.

Doerr, M., Bekiari, C., Bruseker, G., Ore, C-E., Stead, & Velios, S. T. (Eds.). (2020). *Definition of the CIDOC conceptual reference model*. Volume A. ICOM/CIDOC Documentation Standards Group and CRM Special Interest Group. Version 7.1, October 2020. Retrieved 28th October, 2020, from: http://www.cidoc-crm.org/sites/default/files/CIDOC%20CRM_v.7.0.1_%2018-10-2020.pdf

Eerkens, J. W. & Bettinger, R. L. (2001). Techniques for assessing standardization in artifact assemblages: can we scale material variability? *American Antiquity*, *66*(3), 493–504. https://doi.org/10.2307/2694247

Eiteljorg, H. (2004). Computing for Archaeologists. In S. Schreibman, R. & J. Unsworth, *A companion to digital humanities* (pp. 20–30). Oxford: Blackwell Publishing.

Frege, F. L. G. (1903). *Grundgesetze der Arithmetik*, Vol. 2. Jena: Verlag Hermann Pohle.

Ford, B. (Ed.) (2011). *The Archaeology of Maritime Landscapes*. New York: Springer. https://doi.org/10.1007/978-1-4419-8210-0

Furuta, R., Monroy, C., & Castro, F. (2007a). Ancient technical manuscripts: the case of 17th-century Portuguese shipbuilding treatises. In S. Schmidt, R. Siemens, A. Kumar & J. Unsworth (Eds.), *Digital Humanities 2007 Conference Proceedings* (pp.67–69). Urbana-Champagne: University of Illinois.

Furuta, R., Monroy, C., & Castro, F. (2007b). A multilingual approach to technical manuscripts: 16th and 17th-century Portuguese shipbuilding treatises. In E. Rasmussen (Chair), *Proceedings of ACM/IEEE Joint Conference on Digital Libraries* (pp.413–414). Vancouver, BC, Canada.

Hill, R., (1994). A dynamic context recording and modeling system for archaeology. *International Journal of Nautical Archaeology, 23*(2), 141–145. https://doi.org/10.1111/j.1095-9270.1994.tb00453.x

Huggett, J. (2012a). Lost in information? Ways of knowing and modes of representation in e-archaeology. *World Archaeology*, *44*(4), 538–552. https://doi.org/10.1080/00438243.2012.736274

Huggett, J. (2012b). Core or periphery? Digital humanities from an archaeological perspective. *Historische Sozialforschung,* 37 (3), 86–105. https://doi.org/10.12759/hsr.37.2012.3.86-105

Klimovsky, G. (2005). *Las desventuras del conocimiento científico*. Buenos Aires: A-Z Editora.

Kuhn, T. S. (1977). La tensión esencial: tradición e innovación en la investigación científica. In T. Kuhn (Ed.), *La tensión esencial. Estudios selectos sobre la tradición y el cambio en el ámbito de la ciencia* (pp. 248–262). México, D.F.: Fondo de Cultura Económica.

Lock, G. (2003). *Using computers in Archaeology: Towards virtual pasts*. Routledge, New York. https://doi.org/10.1080/00665983.2003.11078213

Lock, G., & Molyneaux, B. (Eds.) (2006). *Confronting Scale in Archaeology*. Springer, New York. https://doi.org/10.1007/0-387-32773-8

Losee, J. (1981). *Introducción histórica a la filosofía de la ciencia*. Madrid: Alianza. Translation of the 1st Edition.

Mach, E., (1959). *The Analysis of Sensations*. New York: Dover Publications.

Manders, M., Oosting, R., & Brouwers, W. (2009). *MACHU Final Report* Nr. 3. Rotterdam: Educom Publishers B.V.

Menéndez, E. (1999). Uso y desuso de conceptos: ¿dónde quedaron los olvidos? *Alteridades*, *9*(17): 147–164.

Mill, J. S. (2002). *A System of Logic*. Honolulu: University Press of the Pacific.

Monroy, C., Parks, N., Furuta, R., & Castro, F. (2006). The Nautical Archaeology Digital Library. In Gonzalo et al. (Eds.), *European Conference on Digital Libraries 2006 LNCS 4172* (pp. 544–547). Berlin and Heidelberg: Springer-Verlag.

Monroy, C., Furuta, R., & Castro, F., (2007). Texts, illustrations, and physical objects: the case of ancient shipbuilding treatises. *11th European Conference on Research and Advanced Technology for Digital Libraries ECDL*, Budapest, Hungary.

Monroy, C., Furuta, R., & Castro, F. (2009). Ask not what your text can do for you. ask what you can do for your text (a Dictionary's perspective). *Digital Humanities.* University of Maryland, MD: College Park. 344–347.

Monroy, C., Furuta, R., & Castro, F. (2010). "Using an ontology and a multilingual glossary for enhancing the Nautical Archaeology Digital Library". *Joint Conference on Digital Libraries JCDL*, Queensland, Australia, 259–262.

Muckleroy, K. (1976). The integration of historical and archaeological data concerning an historic wreck site: The 'Kennemerland'. *World Archaeology, 7*(3), 280–289. https://doi.org/10.1080/00438243.1976.9979641

Muckleroy, K. (1978). *Maritime Archaeology*. Cambridge University Press.

Nagel, E. (1961). *The Structure of Science: Problems in the Logic of Scientific Explanation*. New York, NY: Harcourt.

Nieto Prieto, X. (1997). Le commerce de cabotage et de redistribution. In P. Pomey (Ed.), *La navigation dans l'Antiquité* (pp. 146–159). Aix-en-Provence: Edisud.

Pomey, P. (2011). Defining a ship: architecture, function, and human space. In A. Catsambis, B. Ford & D. L. Hamilton (Eds.), *The Oxford Handbook of Maritime Archaeology* (pp. 25–46). Oxford: Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199336005.001.0001

Popper, K. (1959). *The Logic of Scientific Discovery*. New York: Basic Books.

Sautu, R. (2005). *Todo es teoría. Objetivos y métodos de investigación*. Buenos Aires: Lumiere.

Schiffer, M. B. (1972). Archaeological context and systemic context. *American Antiquity*, *37*(2), 156–165. https://doi.org/10.2307/278203

Schiffer, M. B. (1987). *Formation Processes of the Archaeological Record*. Albuquerque: University of New Mexico Press.

Shanks, M. & McGuire, R. H. (1996). The craft of archaeology. *American Antiquity*, *61*(1), 75–88. https://doi.org/10.1017/S0002731600050046

Steffy, J. (1990). Problems and progress in dating ancient vessels by their construction features. In H. Tzalas, (Ed.), *Tropis II, Proceedings of the 2nd International Symposium on Ship Construction in Antiquity* (pp.315–320). Athens.

Steffy, J. (1995). Ancient scantlings: The projection and control of ancient hull shapes. In H. Tzalas, (Ed.), *Tropis III, Proceedings of the 3rd International Symposium on Ship Construction in Antiquity* (pp.417–428). Athens.

Thomas, J. (2015). Why 'The death of Archaeological Theory'?. In C. Hillerdal & J. Siapkas (Eds.), *Debating Archaeological Empiricism: The Ambiguity of Material Evidence* (pp. 11–31). London: Routledge.

Tudhope, D., Binding, C., Jeffrey, S., May, K., & Vlachidis, A. (2011). A STELLAR role for knowledge organization systems in digital archaeology. *Bulletin of the Association for Information Science and Technology, 43*(5), 15–18. https://doi.org/10.1002/bult.2011.1720370405

Torres, R. (2017). Arqueologia Histórica na Era Digital. *Revista Latino-Americana de Arqueología Histórica, 11*(1), 7-19. https://doi.org/10.31239/vtg.v11i1.10547

Weitz, M. (1977). *The Opening Mind. A Philosophical Study of Humanistic Concepts*. London: University of Chicago Press.

Westerdahl, C. (1992). The maritime landscape. *International Journal of Nautical Archaeology, 21*(1), 5–14. https://doi.org/10.1111/j.1095-9270.1992.tb00336.x

Wittgenstein, L. (2006). *Sobre la certeza*. Barcelona: Editorial Gedisa, S.A.

Vidal Torres Caballero, J. (1994). Reflexiones sobre la terminología lingüístico-gramatical. *Cauce: Revista de filología y su didáctica,* 17, 83–106.

Zeltwanger, H. (2015). A short history of standardization and CAN. *Control Engineering*, Digital Edition, February 16. Retrieved July 29th, 2020, from: https://www.controleng.com/

Zubrow, E. (2006). Digital Archaeology. A historical context. In T. Evans and P. Daly (Eds.), *Digital Archaeology. Bridging method and theory* (pp. 8–26). London: Routledge.