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Tesi di Laurea

IN-SITU CONSERVATION OF THE SHIPWRECKS IN THE MEDITERRANEAN SEA

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ABSTRACT

The main objective of this thesis is to carry out a complete analysis of all the key factors that positively or negatively affect the conservation of archaeological material in order to find the best possible way for the implementation of in-situ conservation of shipwrecks in the Mediterranean Sea. It must be kept in mind that in-situ conservation in the Mediterranean Sea is a very complicated process that requires a multidisciplinary approach and analysis of the most important parameters and factors. For this reason it was necessary to break down the entire problem into its basic components (definition, value and importance of the process of formation of shipwreck sites, the greatest threats that jeopardize it) in order to better understand and find a more efficient method for protection and in-situ conservation of shipwreck sites.

In addition, this complex analysis will be supported from the theoretical point of view, as well as by the latest researches conducted in the area of the Mediterranean Sea in order to determine the real potential for the conservation of shipwrecks. It is known that the Mediterranean Sea does not provide good conditions for conservation and that the main problems associated with in-situ conservation in the Mediterranean Sea are related to natural environmental conditions, more precisely, physical and biological impacts, but also the human factors that have the greatest influence on the degradation of a shipwreck. For this reason, a large part of the thesis will be devoted to the analysis of these factors and the potential danger that they pose to a shipwreck site. It is highly important to understand how significant their impact on the degradation of archaeological shipwreck sites is, and that the future protection methods and in-situ conservation will mostly depend on them.

Also, will be necessary to provide an argumentative reflection and comparative analysis of the methods and results of studies that have been applied in other areas. For this reason, the importance of projects that were carried out in the Baltic Sea in recent decades must be noted. Discoveries and conclusions from these projects have made a great contribution in the field of in-situ conservation and gained experience and knowledge have enabled the use of this method even in conditions that are significantly different from the Baltic, like, for example, in the area of the Mediterranean Sea.

1. INTRODUCTION

We live in a very dynamic world of constant and frequent natural and social changes, and with the development of our civilization, it is becoming even more dynamic. As we build and construct what will one day become only the remains of our civilization, at the same time, we destroy the material remains and accounts of human life from the past that have survived to this day. Archaeological shipwreck remains are very limited and vulnerable, and the only way to ensure the survival of this underwater cultural heritage is to design and implement a new method that will protect them from damage and destruction. These shipwreck sites must be studied and used very carefully as unique and nonrenewable resources that could easily be destroyed and lost forever without some long-term plans. (De la Torre, 1995)

Underwater archeology deals with a systematic investigation of human past, behavioral and cultural activities, using the material remains of the past, including archaeological sites, structures and artifacts and other findings that can be found buried in the earth, beneath the surface of salt or fresh water seen on the bottom or hidden beneath marine sediments and may contain the remains of shipwrecks, boats, architectural structures and other cultural materials from the past.[1]

There are many definitions for underwater archeology. Each of these definitions could possibly be correct, because none of them is wrong, although not precise enough to be able to clearly define a specific scientific discipline. It depends primarily on the general division of underwater archeology at its sub disciplines that are often very specialized in various aspects, such as a specific historical period, the study of the culture of a

[1] Gibbins, D., Maritime archaeology. In A *Dictionary of Archaeology*, eds I. Shaw and R. Jamieson, Oxford: Blackwell, (2000), pp.230-233.

particular region, particular archaeological materials, or man's relationship and connection with the sea, which can involve the study of objects beneath the surface of the sea and those which are on dry and that could have a direct relationship with that attitude. When these aspects of underwater archeology are studied, there are different approaches and methods that can be used for this purpose.[2] The main difference between these approaches and methods as well as a more precise term that defines the difference between underwater, maritime, nautical and marine archeology is primarily related to a variety of environments and interests that direct research towards a specific topic, but also the type of evidence that can be used in these studies. It might be more accurate to say that underwater archeology includes specific methodological and technical approach to work below the surface of the water while all other subgroups can be defined, as part of maritime archeology and because of its comprehensiveness and complexity the maritime archeology requires subsequent division into sub disciplines with a particular specialty.

Probably the most developed of all the sub-disciplines of maritime archeology, deals with the study of historical context, whose main task is not only the study of historical sources and the precise sequence of historical events but discovering and understanding the actual reasons and causes for all these events.

Another important interest of maritime archeology is a sociological aspect, its main objective being the study of human societies, cultural practices, and activities, as well as the study of traditions and customs. In this case, it refers to ethnographic characteristics of distinct communities of the past but also their mutual contacts and relationships within a specific period. Familiar subjects are related to the study of certain archaeological material such as the amphorae that were used in the past to transport liquids and foodstuffs.

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[2] Muckelroy, K. (1998). Introducing maritime archaeology. In L. E. Babits, & H. Van Tilburg, *Maritime archaeology: a reader of substantive and theoretical contributions*, New York: Plenum Press, pp. 3-24.

Once again, as in the previous case, the study may be directed to the human community that produced the material but also the interconnections between these communities and other remote communities with which they had economic and commercial exchange of goods. Finally, scientific interest may be related to the study of architectural structures that remain more or less preserved under the water or on land. These objects can give very important information about human activities in the past, the level of economic, cultural and technological development.[3]

Certainly, one of the most important aspects of maritime archeology is the study of remains of shipwrecks, which can also sometimes be found in very unusual and unexpected places and in different environments.[4] In this case the object of scientific research would be quite different, highly specialized and focused on the study of the evolution of technological development in ship building and construction, maritime routes, type of cargo and the commercial relationships between different geographic areas.[5]

There is an obvious fact that all these aspects of maritime archeology, as much as they have different interests or how much they vary in their methodological approach, are strongly connected with each other and therefore it is practically impossible to study the archeological shipwreck site or certain archaeological material in isolation and in itself .

All archeological sites are by their morphology, structure, the way they are formed and where they are located, very different. In general, we can say that every shipwreck site represent certain archaeological sources of information.[6]

[3] Maarleveld, T. J., Type or technique: some thoughts on boat and ship finds as indicative of cultural traditions, *International Journal of Nautical Archaeology*, vol.24, (1995). pp. 3-7.

[4] Martin ,C., Sutton Hoo-Burial Ground of Kings, British Museum, Press, (1998), pp.2-52

[5] Ward, C., Boat-building and its social context in early Egypt: interpretations from the First Dynasty boat-grave cemetery at Abydos, Department of Anthropology, Florida State University, vol.80, (2006): pp.118–129

[6] Bowens, A., Underwater archaeology: the NAS guide to principles and practice, Blackwell Pub. (2009), pp.22-28

At first, we think of the archaeological material, which can be found at archaeological sites. For this reason, we can say that an shipwreck site, regardless of the era to which it belongs and where it is located, is the concentration of closely related archaeological material and findings that are a testimony to the life of people and their communities in the past. A careful and methodical study of these archaeological sites and cultural findings contained in them as well as using various multi-disciplinary analyses and a whole range of different methodological approaches, results in a group of archaeological materials that are contextually linked to each other.

In other words, we have a whole range of information that allows us to get a bigger picture and context of a particular archaeological site but also its interconnection with other sites.[7] These sites, each of them, represent only a small part of global archaeological resources, in other words, they represent a small element of a very dynamic and very broad cultural and historical context.[8]

An underwater archeological site containing the remains of shipwrecks, can serve as an excellent example to substantiate this claim because the site also contains the most diverse concentration of archaeological material such as cargo that is being transported or personal items belonging to the crew. That archaeological material can eventually help to learn and understand the type and purpose of the ship[9], what the life was like on the ship, the maritime route that the ship took, the port from which it started sailed out, the point where it stopped while traveling, but we can also assume its final destination.

Furthermore, we can get information on the construction of the ship, the wood, and other materials used in shipbuilding and its geographical origin, as

[7] Bowens, A., *Underwater archaeology: the NAS guide to principles and practice,* Blackwell Pub. (2009), pp.22-28

[8] Gibbins, D., Ancient maritime economics: a view from the Mediterranean. In Where Deva Wends her Weary Stream: Trade and the Port of Chester (ed. P. Carrington). *Chester Archaeology Monographs 4. Chester Archaeology*, (1996) pp.45- 67.

[9] Casson,L., Ancient shipbuilding ; New light on an old source Transactions of the American Philosophical Association 44, (1963), pp. 28-33

well as the equipment that was on the ship. This primarily refers to guns and other combat equipment that the ship was possibly armed with.[10]

Finally, by conducting careful analysis of the shipwrecks and archaeological materials scattered around the site on the bottom, or later in the laboratory we can understand the reasons for its sinking and reconstruct its last moments.

If we take the above-mentioned or any other archeological site as an example, we can conclude that the main purpose and intention of maritime archeology and all its sub-disciplines, is to unify and study all the available archaeological data through a wider study of the human past. The results of these studies have given a huge contribution not only to our understanding of man's relationship to the sea and the marine environment, but they have also enabled us to grasp a complex picture of the whole human history.[11] It is particularly important anthropologically oriented, approach to the study of shipwrecks, which no doubt means that the main objective of the research is ultimately a man, not ships, cargo, instruments, tools and other archaeological material that can be found.[12]

It is of great importance, and also at the great advantage of archaeological shipwreck sites that, as in most cases, the archaeological material in them is extremely well preserved, much better than, for example, under the ground. The degree of preservation is directly related to the conditions under which the site is located, the manner under which the archaeological site was formed, but also these conditions dictate whether the material remains will be seen on the sea floor or buried beneath sediment.[13]

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[10] Pomey, P., Defining a ship Architecture, Function, and Human Space, in *The Oxford Handbook of Maritime Archaeology,* (ed) Catsambis, A., Ford, B., Hamilton, L. (2011), pp. 25-46.

[11] Gibbins, D., Analytical approaches in maritime archaeology: a Mediterranean perspective. *Antiquity 64,* (1990) pp. 376-389.

[12] Muckelroy, K., *Maritime Archaeology*, Cambridge University Press. (1978), pp. 3-10

[13] Adams, J., Gibbins, D., Shipwrecks and maritime archaeology, *World Archaeology Vol. 32.3,* (2001), pp. 279- 291

This fact is of great importance given that the conservation of archaeological material and its duration in time, depends primarily on the degree of natural protection of the archaeological site and it is logical that the unprotected material, which is subjected to external environmental influences over the time, will suffer more physical and chemical changes to the moment when it will be completely destroyed. In addition, the degree of preservation, potential vulnerability, and the state of the archaeological material on the underwater archaeological site as well as the morphology and environment decide on our approach to the valuation and the methods of conservation of the same material.

Keeping in mind the importance of shipwreck sites and the information they can provide and the fact that for various reasons many of them are endangered or may be at potential risk of permanent destruction, as a logical conclusion there is a need to develop certain types of future strategies that would aim, above all, at the protection of such sites and their intention to research and study.[14] This is primarily related to several important subjects that could contribute to the future development in the field of maritime archeology and related to the field of research, legal provisions and protection - conservation.[15]

The research is an area that has experienced remarkable growth, primarily due to the development of very sophisticated equipment and methodological approaches that have enabled the discovery of many archaeological sites and their efficient research and study, which consequently gave a great contribution to the study of the human past.

The process of improvement has not been completed yet and we are daily witnessing the development of new instruments and equipment. In the future, more attention should be paid to the systems for monitoring of archaeological sites.

[14] Andrews, G., Barrett, J. C., Lewis, J. S. C., Interpretation not record: the practice of archaeology, *Antiquity, vol. 74,* (2000), pp. 525-530.

[15] Firth, A., Ferrari. B., Archaeology, and marine protected areas, *International Journal of Nautical Archaeology, vol. 21,* (1992), pp. 67-70.

Such (satellite) systems already exist but their use is limited mainly to military needs and for this reason, and because of their very high prices, they have not yet entered into wide use for civilian purposes.

In addition, a big problem that requires special efforts is related to archaeological excavations in the conditions of limited visibility, which can occur in rivers, lakes and lagoons or strong currents and in particular, it refers to the research on archaeological sites in the deep sea.

Another important aspect relates to the legal provisions and the legal acts that regulate and safeguard the historic cultural heritage. Unfortunately, it is known that the legal provisions that promote and protect the cultural and historical heritage, differ from country to country and often they are not of high priority. Their disrespect or lack thereof is often abused by individuals or groups whose interest is mainly of material nature and the preservation of historical and archaeological values of global and national significance are of minor importance. For this reason, an engagement is essential at all levels, as well as the insistence on informing and educating the public with the aim of ensure more responsible attitude to cultural heritage.[16] It is necessary to define that underwater cultural heritage is not private property or the property of a single individual or a country, but a global cultural heritage, which therefore requires cooperation among states or some sort of broader, regional cooperation in order to achieve the objective. The safest and best solution to this problem would be to identify areas of special cultural and historical significance, which should be rigorously physically and legally protected from all economic and commercial activities including sport diving.

The third, and perhaps most important aspect is the development of future archaeological protection, preservation and conservation of archaeological material. It is a very complex area whose efficient implementation requires a multidisciplinary approach that primarily involves the development of future analysis and methods in the laboratory as well as new materials for efficient

[16] Kaoru, Y., Hoagland, P., The Value of Historic Shipwrecks: Conflict and Management, in *Coastal Management, vol. 22*,(1994), pp. 195-213.

conservation. It also requires training of professional staff who would deal with research and conservation. Their task would be to choose the most efficient methodological approach, keeping in mind that every archaeological site is unique and therefore requires a unique methodology, and to decide which objects should be left and protected in situ, but also which types of findings should be taken out of the water and after protection and conservation, be exhibited on a permanent or temporary exhibition or museum display. After years of research and development in the field of underwater archeology, it was concluded that a very limited human intervention in this highly sensitive environment, is perhaps the best way to preserve the archeological shipwreck site. Of course, nothing is eternal, and it is practically impossible to completely stop the deterioration of archaeological materials and even those that were protected in situ. However it is important to take all measures to protect them and try to extend their duration as far as possible over time. These underwater sites can serve as a kind of archive that is always available for monitoring and which will at the same time remain completely preserved for future generations when it will be investigated by means of more sophisticated methods and techniques than those that we now possess.

2. IMPORTANCE OF SITES

2.1. THE SIGNIFICANCE AND VALORIZATION OF SHIPWRECK SITES

2.1.1. INTRODUCTION

UNESCO Convention on the Protection of Underwater Cultural Heritage (Paris 2001) defines cultural heritage as "... all traces of human existence and activities that have cultural, historical or archaeological character and who are temporarily or permanently, partially or totally under water, at least 100 years ..."[17] The adoption of this definition is a controversial process because by itself it does not give a realistic idea about what is the real value of underwater archaeological sites and has certain limitations that are primarily related to sites of cultural importance that are treated as more important than others. As a result, it is necessary to determine the precise concept that defines the importance of underwater archaeological shipwreck site, which depends on the value that it has for the community and that value is the main reason for its preservation. It is clear that no society has no interest in to preserve what is not considered as value. This means that it is necessary to fully understand the nature and importance of a particular shipwreck for a society, for protection, conservation and preservation of values that place, which requires adequate assessment without which it risked reducing the importance and the destruction of important aspects of the site. [18]

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[17] UNESCO,, *Convention on the Protection of the Underwater Cultural Heritage*, UNESCO, Paris,(2001).

[18] Adams, J. (2001). Ships and boats as archaeological source material. *World Archaeology 32.3*, pp. 292-310.

Importance of the cultural-historical heritage refers to the values that it has for the community, but precisely these values is very difficult to define when they are used in this context. The reason for this is because that importance has no economic value, but aesthetic and historical significance as well as ethical uniqueness, which are based on internal standards prescribed and directly related to the socio-cultural and spiritual legacy of the past of a community.

Evaluating the importance of shipwreck sites by different segments of society depends on many different factors and the value that they attribute to these sites is very subjective. These stakeholders do not have the same understanding and evaluating systems and their vision of what is important about underwater archaeological sites is often very different, or even in direct conflict. [19]

For scientists these shipwreck sites are important because they are the subject of research in which base their academic work, career advancement, and reputation. For some nations, they are of great importance since they connect and interpret their national and ethnic identity with those underwater archaeological sites or glorifying important and glorious moments in its history. For some countries, they are also important because the state realized a very large economic benefit through tourism and owe their economic well-being thanks to a very important and popular cultural and historical sites and findings.[20] On the other hand, there is a social organization whose main interest in economic and industrial development, and that for the sake of development, partially or completely disrespect the value of cultural and historical heritage and monuments. Adequate evaluation and effective protection of shipwreck sites requires a clear vision

[19] Kaoru, Y. & Hoagland, P., (1994), The Value of Historic Shipwrecks: Conflict and Management, *Coastal Management*, 22: pp.195-213.

[20] The new Vasa museum was opened in 1990 and attracts between 730,000 and 1.2 million visitors every year. The museum is one of most visited museums and an enormous economic asset for the Stockholm region and Sweden in general. This success as a national icon is partly due to strong narratives, an excellent visitor service, and a successful long-term marketing strategy. UNESCO (2013),

on what is the importance of an archaeological site and what is worth to be protected and what are the dangers that threaten the site.

For this reason, it is very important that in the process of assessment involve all key stakeholders from many social spheres of influence, and the evaluation must be articulated according to their specific interests. This would avoid that one group put their own interests ahead of the interests of others. This task is actually the biggest challenge for archaeologist and conservators because it is actuality very difficult to meet all stakeholders.

The most important thing is that those who have the task of evaluation and preservation of archaeological shipwreck site, ensuring that these sites should be used by the society in ways that do not sacrifice the elements that give significance to these sites.

2.1.2. SCIENTIFIC AND EDUCATIONAL IMPORTANCE

The value of underwater archaeological shipwreck sites in the Mediterranean sea, can be clearly understood if viewed as some kind of benefit or general welfare of the community.[21] In addition, when the shipwreck site is used for useful and creative purposes such as scientific research or education of citizens and in this case the site is not only material residues but symbolizes something much bigger and more important. The site can provide lessons of history, art, celebrate and preserve the memory of a very important event from the past or even enable the development of local society. In this case, the importance can be understood as a "positive effect" on the community and promote culture and its national image, arising directly from the existence of this site. The potential value of the shipwreck site can be viewed through the future scientific work and information that can be obtained. In the past, the purpose of the archaeological excavations was to get to the material values to fill the museums or private collections. Today, the reason for underwater research is to develop reasonable and constructive answers to important questions and hypotheses. Archaeology as a discipline for this purpose uses numerous findings and evidence from the field to acquire new knowledge that can and must be properly interpreted and understood by the public and not just as a means of attracting more visitors and tourists. Good interpretation and availability, enables and helps visitors to museums and archaeological sites to understand archeology as well as raising awareness about the importance of this site to society and thus can convert them into a big proponent or even activist for future archaeological research and conservation. Innovative methods of interpretation and presentation of shipwreck sites of cultural significance, as well as cost-effective and self-sustaining methodology, as a result of have a completely new approach.

[21] Deeben, J., Groenewoudt, B. J., Hallewas, D. P. & Willems, W. J. H., (1999), Proposals for a practical system of significance evaluation in archaeological heritage management, *European Journal of Archaeology 2.2*: pp. 177-199.

In fact, in recent years, some countries have begun to use the funds gained through tourism and public display for scientific research and study as well as to further preservation and conservation of cultural heritage.[22]

[22] De la Torre, M., & MacLean, M. (1995). *The Conservation of Archaeological Sites in the Mediterranean Region,* The Getty Conservation Institute Los Angeles pp. 5-14.

2.1.3. MEMORIAL SIGNIFICANCE

The third very important aspect of the evaluation of shipwreck sites refers to the memorial sites. Evaluation and attitude that the community has toward these sites is extremely complex and delicate. Different structures of society have very different views on them and understanding how these sites should be treated. This problem is based on the dilemmas that depend on the ethical and cultural-historical heritage, religious beliefs, relationship with the deceased and what it represents for the community.[23]

Human remains that could be found on the archaeological sites cause very much attention among scientists and are considered for findings of exceptional value because they can provide very important information[24]. Modern methods of research and the use of medical science in paleopathology and the possibility of isolating human DNA, can provide answers to the fierce debates about human evolution and enables complete reconstruction of human life and human activity from prehistoric times.

It is quite a different situation when it comes to a historic site or location of a recent date, precisely because there is the memory of the events and people that are in these events lost their lives. This imposes an obligation to the whole community to relate with full of respect for these sites. In addition, it is necessary to find ways to adequate protection and conservation and the provision from excessive disturbance of the site. This primarily involves unnecessary visits, constructional and other works as well as navigation.

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[23] Maarleveld, T.J.; Guérin, U.; Egger, B. (Ed.) (2013). Manual for activities directed at underwater cultural heritage: Guidelines to the annex of the UNESCO Convention. UNESCO: Paris,(2001), pp.346-348

[24] Beltrame, C., (2008), Elementi per un'Archeologia dei Relitti navali di età moderna; L'Indagine di scavo sottomarino sul Brick Mercurio, *Missioni Archeologiche e progetti di Ricerca e Scavo, VI Giornata*, pp. 219-227

In the Mediterranean and the Adriatic Sea there are a large number of underwater archaeological sites which are memorial monuments that mark and preserve the memory and the remembrance of the great naval battles, tragic events, and loss of life. At some of these locations may still find human remains as a testimony of great accidents and sufferings. (Picture 2.1)

Picture 2.1 Remains of a human skeleton on the underwater site of Mercure, Lignano, Italy. (Photo documentation Stefano Caressa)

Some of the the better known shipwrecks are Baron Gautsch that sank at the beginning of World War I in 1914. years and who pulled with him to death 273 lives, mostly women and children, or Austro-Hungarian battleship Saint Isztvan which was sunk on 9 June 1918. the nearby islands Premuda. These shipwrecks were under the protection of the state of Yugoslavia and later Croatia for last fifty years. Although they do not enter in the category of underwater cultural archaeological heritage in the classical sense, but they were protected because of its historical and memorial significance. (Picture 2.2)

Also of great importance is the shipwreck “Mercure” that was sunk near Lignano (IT) in 1812.[25] This shipwreck has multiple national importance for Italy because it was the first ship to sail under the Italian flag.

At this site are found artillery weapon that can be used to study the history of the ship's weapons and a large number of personal items that have been found can be used to write down the history of life on a warship that period. Certainly, the huge significance of the site is that it is one of the few of historical shipwreck in which was found a large number of human skeletons[26] ranking it among the underwater memorial sites of great importance

Picture 2.2 Wreck of the SMS Szent Istvan, an Austro-Hungarian warship, found near Premuda, Croatia.(Photo documentation of the Croatian Conservation Institute)

[25] C. Beltrame, L. Fozzati, Lo scavo del relitto del brick del Regno Italico Mercure (1812). Formazione e ricerca in archeologia marittima sui fondali di Punta Tagliamento, in A. Zaccaria, ed., *Le missioni archeologiche dell’Università Ca’ Foscari di Venezia. Giornata di studi, Venezia*, (2006), pp.167-174.

[26] Bertoldi F. I resti osteologici umani, in L.Fozzati , *Caorle archeologica. Tra mare, fiume e terra,* Venezia,(2007), pp. 147-149

There are so many other examples of memorial underwater sites in the Mediterranean. The reason for their occurrence may be intentional burials ("Blue Graveyard")[27] , maritime accidents and shipwrecks, or traumatic war events at sea. What is common for them all is the suffering of people who are directly or indirectly associated with these sites; those who lost their lives but also those who lost their dear and loved ones. For this reason, the main feature of these sites and what is intrinsically valuable about them is that they are more than any other cultural monuments symbolize interpersonal relations and most directly links the past and present.

[27] "Blue Graveyard" island Vido (Corfu, Greece), Mausoleum from the World War I dedicated to over 10000 Serbian soldiers and recruits died and buried on the island and the surrounding sea, after the retreat across Albania 1916.

2.2. THE LEGAL PROTECTION OF UNDERWATER CULTURAL HERITAGE

Sunken ships, buildings and other hidden and valuable findings from the depths of the sea, has attracted great attention of people and provoked a desire to reach them. Motives for access to these sunken traces of past human activities are diverse. Most people are driven by human curiosity and desire for knowledge and understanding of the events that occurred in the past. For other people, the main motive is to acquire wealth by unauthorized collecting of rare and valuable items or property from the seabed.

The vastness of the sea around the world as a kind of art collection, kept at its bottom a huge number of shipwrecks and material remains of archaeological, historical and cultural significance, but also a large quantity of items of great financial and artistic value, which caused great attention of looters and treasure hunters. For a long time, these remains are lying deep under the sea and were inaccessible to humans. Eventually, thanks to human progress this obstacle has been overcome and valuable cultural findings, which for centuries lying on the seabed hidden and well preserved, have become available for the visit and research.

Regardless of the intent and motivation, people were constantly inquiring and consequently discovered all the easier ways to develop technologies, which allow access and work at great depths. These technologies have created a prerequisite for the development of many scientific disciplines including underwater archeology and for the scientists have always been of great help for development and improvement new approaches and methodology of research and documentation of underwater sites. However, the greatest merit of new technologies is reflected in commercial development, which often directly or indirectly threatens sites.

Activities such as underwater excavation, drilling, laying pipelines and cables but also the uncontrolled fishing and tourism lead to a greater and greater risk of damage or even destruction of shipwrecks and material residues that are located in the Mediterranean.[28]

Certainly, the major danger to the underwater cultural heritage threatened by looters, unauthorized international enterprise for underwater research and treasure hunters which are not interested in scientific research and conservation of the discovered material. Their main motive is financial profit and wealth.[29] There are plenty of examples where various private companies have find and pull out from the seabed material of great cultural and aesthetic values Much of this material is sold to illegal private auctions and its scientific and cultural value is being lost forever.[30]

It is very difficult to estimate with certainty the amount of illegal trade that involves objects of cultural value. Certainly, recent research has shown that the illegal market from the Mediterranean region is much greater than it previously estimated.[31]

In favor of the unauthorized exploitation of cultural heritage, is the fact that scientific institutions as authorized state institutions that deal with research and protection of cultural property are often not able to provide the necessary money for the work. Commercial researchers are therefore in a great advantage and are very successful in marine exploration and exploitation. Despite the fact that their projects are sponsored from the private budget, they were able to recover money for research confirming their right to possession and sale of cultural finds excavated from the

[28] Scovazzi, T., The Convention on the Protection of Underwater Cultural Heritage. In: *Environmental Policy and Law, Vol. 32, No. 3-4,* (2002), pp. 152-157.

[29] Merryman, J.H., A licit international trade in cultural objects, *International Journal of Cultural Heritage vol.4.1*0, (1995), pp. 13–60.

[30] Bekic,L., Underwater Cultural Heritage and the UNESCO Convention, in *Conservation of underwater Archaeological Finds*, Zadar,(2011), pp. 7-13

[31] Pastore, G., *The looting of archaeological sites in Italy*, in Brodie et al. (eds.), 2001,pp. 155–160

water[32], which is in direct conflict with the interests of the scientific community and the public who have an interest in protecting and preserving cultural heritage.[33] This conflict of interest and ethical disagreements intensified the debate over the ownership and management of underwater sites.

With the growing scientific and public interest in the archaeological resources and vulnerability of cultural heritage under water, which was discovered by the authorized but also by private corporations engaged in unauthorized research and trade, the countries of the Mediterranean region and the whole international community become aware of the importance of establishing an effective legal regime.[34]

Considering the seriousness of the problem as well as its international character, the inevitable was involvement of international institutions towards solving this conflict. Reconciliation between the private with the public interest in order to protect underwater cultural resources must be governed by international law and its preservation of these resources must be defined as a key element of economic, social, and cultural development.[35]

As the final result of years of international initiatives and attempts, in 2001. has been adopted the Convention on the Protection of the Underwater Cultural Heritage. The Convention is a very important achievement in international legal protection at the global level and provides the basis without which it would be unimaginable permanent protection and conservation of underwater archaeological sites.

Unfortunately, the practice of the Mediterranean and the Adriatic Sea in recent years has shown that adopted international conventions is unable to

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[32] Vadi, S., Investing in Culture: in *Underwater Cultural Heritage and International Law*,(2009), pp. 855-863

[33] Frost, R., Underwater Cultural Heritage Protection, *23 AUST. YBIL* (2004), page 25-29

[34] Scovazzi ,T., *The application of Salvage Law and Other Rules of Admirality to the Underwater Cultural heritage*, Lieden, (2003), pp.193-203

[35] Pearlstein, W.G., Claims for the repatriation of cultural property: prospects for a managed antiquities market, *Law and Policy International Business vol.28*, (1996), pp. 123–150.

fully ensure the archaeological sites which despite the strict regulations, are disturbed and looted.

As an answer to activities of robbers, one of the potentially effective methods could be the physical protection with protective cage, which has been applied for several years on the coast of Croatia.[36]

[36] Zmajic, V., The Protection of Roman Shipwrecks „in situ". Underwater Museums, in: Miholjek, I., Bekic, L.,. (ed.) *Exploring Underwater Heritage in Croatia*, Zadar, (2009), pp.18 - 19.

3. PROCESS OF THE FORMATION OF AN ARCHAEOLOGICAL SHIPWRECK SITE IN MEDITERRANEAN SEA

The process of formation of the underwater archaeological site is a very complex process that consists of natural and cultural processes that influence the creation and conservation of archaeological record.[37] While natural processes represent environmental influences, cultural processes include all unintentional and intentional human activities that negatively or positively affect the formation of the site and together they represent processes that are crucial factors that determine the dynamics of the formation of underwater archaeological sites.

Natural environment and its characteristics have a fundamental role in the creation of underwater archaeological sites and the specific environmental conditions will enable better conservation and longer survival of archaeological finds of certain materials or otherwise facilitate their rapid decay. Study of the natural environment of the underwater sites, as well as their chemical, physical, and biological characteristics is an important part of archaeological research. Precisely these characteristics will be crucial in determining the techniques and methods that will be most effective during the archaeological survey.

The probability of selection of proper archaeological methods can be increased by a better knowledge of the geomorphological processes at the site, because the problems related to the relationship between the natural ecosystem, geochronology, and in-situ formation and conservation, are interconnected.

[37] Murphy, L., Site Formation Processes, in J. Delgado (ed.) *Encyclopedia of Underwater and Maritime Archaeology*, London,(1997), pp. 386–388.

In other words, the study of these processes enables better comprehension and understanding of the complex dynamics of the formation of underwater sites, which is very useful for further research and conservation.

The study of the formation of underwater archaeological sites has been of great interest in scientific circles in recent decades, and with the recent theories it has become a very important tool in the study of site formation. [38]

The creation of underwater sites is very complex and complicated process, which consists of the mutual relationship between the natural environment and the complex mechanism of the destruction of the ship, its deposit, and subsequent distribution of material on the seabed and ultimately stabilization with the surrounding ecosystem.[39]

Given the complexity and diversity of the natural environment, as well as the design, the purpose of the ship and the circumstances of its sinking, it can be noted that there are no two shipwrecks that are identical in appearance and the manner of their creation.[40]

Because of this diversity, the study of the formation of underwater archaeological sites has produced various theories. Most of these theories are aimed at determining the impact of certain factors in the process of formation. Some theorists have focused on the physical and natural impacts on the wreck, while the other gave greater importance to unintentional and intentional impact of human activities on the site.[41] In addition, scientists from earlier phases were trying to develop a single model that could be applied to all or at least most of the sites. (Muckelroy, 1978)

[38] Oxley, I. 1998b, The *in-situ* preservation of underwater sites, in *Preserving archaeological remains in situ*, eds M. Corfield, P. Hinton, T. Nixon & M. Pollard, Museum of London Archaeological Service and University of Bradford, London, pp. 159-173.

[39] Martin, C., Wreck-site formation processes, In *The Oxford Handbook of Maritime Archaeology*, Catsambis A., Ford B., Hamilton D.L., (2011),pp . 47-54

[40] Muckelroy, K., *Maritime Archaeology*, Cambridge University Press. (1978), pp. 3-10

[41] Gibbs, M., , Behavioral models of crisis response as a tool for archaeological interpretation—A case study of the 1629 wreck of the VOC Ship Batavia on the Houtman Abrolhos Islands, Western Australia, in J. Grattan and R. Torrance (eds),*Natural Disasters, Catastrophism and Cultural Change*, New York., (2002), pp.66–86.

Later, in newer and improved theories, scientists have tried to analyze and increase the knowledge of the physical, natural and cultural processes and their sub processes creating models that more accurately explain the phenomenon of creation and evolution of shipwrecks.

3.1. THE DYNAMICS OF THE FORMATION OF THE SHIPWRECK SITE

3.1.1. EARLY THEORY

Muckelroy is the first maritime archaeologist who theoretically and a schematically presented one shipwreck and the process of the formation of underwater sites as a single closed system which consists of the original structure and contents of the ship. During the formation process, the system goes through a series of transformations through interaction with the external environment, which makes the dynamic phase of the process, in order to achieve a final, stable, and disorganized phase in relation to the environment. This statement is in a direct contradiction with recent theories that consider the process of formation of underwater sites as an open system. His analysis shows that the underwater topography and types of sediments are the most important factors that determine the way of the formation of the archaeological site, its preservation, and the conservation of the ship residues.[42]

Although having some weaknesses, Muckeleroy's theory is of great importance and his work would become the basis for many subsequent scientific researches.

[42] Muckelroy K., *Maritime Archaeology*, Cambridge University Press. (1978), pag.160-165

3.1.2. NATURAL PHYSICAL PROCESS OF FORMING SITES

Over the time, the works of archaeologists who studied the natural processes of formation sites have complemented Muckeleroy's theory. One of the most important theories of the period, which relies on the theory of Muckeleroy is definitely the one by Ward (Ward, 1999), which gave perhaps the best explanation of all natural processes that influence the formation of sites in submerged sites which is divided into physical, biological and chemical. Ward notes that an underwater site is a very open and dynamic system in which there is a constant flow and exchange of materials (sediments, water, organic and inorganic materials) and energy (waves and currents).[43]

Research of this natural process has shown that the amount and type of sedimentary deposits around the wreck and the hydrodynamic environment (with high or low energy) has the greatest influence on the formation of the archaeological site and its preservation.[44] In other words, the thickness of the sedimentary layers in combination with the hydrodynamic energy determines how much of the ship's wreckage will be buried and protected under sediments or uncovered and exposed to physical, biological and chemical processes that will cause its degradation. As Ward explains, there is a clear connection between the amount of sediment deposition and hydrodynamics in a certain area. (Ward, 1999) Naturally, the greater sediment deposition, if there is any, depends on the high energy, which is required for the transport of sediment.

This observation suggests that a hard and rocky surface without the presence of sediments will not have great potential for the preservation and conservation of archaeological material in contrast to a soft, muddy substrate

[43] Ward, I. A. K.,A New Process-based Model for Wreck Site Formation, *Journal of Archaeological Science, 26*, (1999),pp. 561–570

[44] Caston, G. F. (1979). Wreck marks: indicators of net sand transport. *Marine Geology* 33, pp.193–204.

with plenty of easily sediment material. (Ward1999) This concept confirms and complements the earlier Muckeleroy's theory.

In his theory Ward also argues that in an environment with a high energy the major factor of the degradation will be the abrasive action of sediment and other fragments carried by strong water currents. Otherwise, in environments with low energy, chemical processes will have the biggest impact on the degradation of a shipwreck with metal construction, while the wooden remains suffer greater degradation due to biological factors. Ward's theory shows that these three elements are not mutually exclusive and that they all work together to achieve homeostasis (balance) between ship remains and the environment. Ward points out that majority of shipwrecks are permanently damaged or destroyed in high-energy environments, where there is a lower sediment layer and where a large part of the wreck remains uncovered and exposed to environmental influences but also the degradation in these environments can be stopped due to re-deposition of sediment layers that form a natural barrier and protection of the sites.

On the other hand, chemical and biological degradation of archaeological material lasts up until the complete degradation of the material and often even the sediment layer is not sufficient protection.[45] The phenomenon of in-situ corrosion of metallic and composite vessels showed a strong correlation between increased corrosion[46] (corrosion potential) and the presence of oxygen, which is directly related to the intensity of water flow. [47]

[45] MacLeod, I.D., (1989a) The application of corrosion science to the management of maritime archaeological sites, *Bulletin of the Australian Institute for Maritime Archaeology*, 32(2), pp. 7-16.

[46] MacLeod, I.D., North, N.A. ,Beegle, C.J., (1986) The excavation, analysis and conservation of shipwreck sites, in *Preventative Measures During Excavation and Site Protection*. ICCROM Conference, Ghent, 1985, pp. 113-131.

[47] MacLeod, I.D., (1998a) In-situ corrosion studies on iron and composite wrecks in South Australian waters: implications for site managers and cultural tourism, *Bulletin of the Australian Institute for Maritime Archaeology, 22*, pp. 81-90.

When we talk about the biological degradation of wood, it is certainly worth mentioning that there is a significant difference between the degradation and conservation in anaerobic and aerobic environment.[48]

The absence of oxygen under the sedimentary layer will prevent the presence of micro and macro-organisms that can damage wooden material and thus provide for better conservation. From the aforementioned reasons, it can be concluded that the physical, biological, and chemical parameters can affect the decay of shipwrecks, but the nature of sedimentation will still be the main factor that determines the degradation and conservation of archaeological material but also the state of equilibrium at the site. Very often, it can happen that a state of balance (homeostasis) is subsequently disrupted by heavy storms that can cause perturbations on the seabed. In addition, the perturbation of the seabed can be caused by intentional or unintentional human influence and this anthropological factor can be defined as a cultural process of site formation, and there is a large number of scientists who have studied this formation process in the last decade.

3.1.3. CULTURAL SITE FORMATION PROCESSES

Gibbs (2006) extended the Muckeleroy's theory in the way that he took into consideration the human factor in the formation of underwater sites. He believes that the phenomenon of the dynamics of the formation of underwater archaeological sites can best be described as a very complex process that will result in the achievement of a state of equilibrium between the sunken shipwrecks and natural environment in which it is located. To achieve a final stable phase the site is required to undergo three distinct phases.[49]

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

[49] Gibbs, M., Cultural Site Formation Processes in Maritime Archaeology: Disaster Response, Salvage and Muckelroy 30 Years on, *The International Journal of Nautical Archaeology35.1,* (2006), pp. 4–19

The first phase or stage of a shipwreck, in most cases is a very violent process and is caused by human behavior that leads to a shipwreck. The second phase is caused by the great influence of the environment, when the wreck due to various factors begins its transformation. These two phases represent unstable and very dynamic part of the process of formation, during which constant changes and modifications are dominant. The third and final phase is a stable one in which transformed ship remains, together with other material remains become a part of a stable natural environment.

Gibbs also emphasizes the fact that a very important prerequisite for the research of the cultural formation of a shipwreck is to know the nature of the shipwreck and the sequence of events. [50]

In his theory, Gibbs points out that it is of great importance to note that there are two basic types of scenarios that are defined as "Shipwreck" and that most of them determine the way in which the site will be formed and the degree of conservation and preservation of archaeological remains on the seabed.

The first category refers to the sites created after the deliberate sinking or abandonment and disposal of ships whereby ships are left in-situ in its entirety and without damage. The reasons for their abandonment are different; obsoleteness due to deterioration or transformation or the use of the ship's construction as "recycled material" for other purposes, even in some cases for votive and funerary purposes. (Schiffer M. B., 1987)

The second category, however numerous, refers to "catastrophic shipwrecks," which means the unintentional loss of the ship due to accidents, collisions, explosions and other violent damage to the ship's structure[51], after

[50] Schiffer, M., *Formation Processes in the Archaeological Record*. Tucson. (1987),pp. 25-47

[51] Murphy, L., Shipwrecks as database for human behavioral studies, in R. Gould (ed.), *Shipwreck Anthropology*, Albuquerque, (1983), pp.65–90.

which the ship usually sinks in a longer or shorter period of time or is simply aground and left on the shore. [52]

Gibbs based his research and his thesis of the cultural formation process on the model used in the research of human behavior in extreme conditions of survival by John Leach. In his book Leach lists a series of extreme conditions, among others, shipwrecks where the human factor is very important, if not decisive for the sinking of a ship and later the formation of the archaeological site at the bottom. The human impact is divided into five main stages, pre-impact, impact, recoil, rescue, and post-trauma.[53]

3.1.3.1. PRE-IMPACT

This phase consists of two sub-phases: the first (threat), which includes all the processes before the shipwreck, which include preparation before sailing out, travel route planning, crew training and ship design. For this phase the archival documentation may be important since it could verify the inadequate planning of waterways route or insufficient crew training. These data are vital because this information is impossible to get during the investigation of archaeological remains at the site. The archival documentation can also give valuable information about the ship's construction, especially information about the possible periodic reparations due to damage, which can often be evident at archaeological sites in-situ during research.

Perhaps the best example to support this theory is the latest research of remains of the Swedish warship "Vasa" which sank in 1628. The ship has sunk on its maiden voyage due to adverse weather conditions and strong wind, exposing their holes for guns, through which the water penetrated and led to the disaster.

[52] Gibbs, M., Maritime archaeology and behavior during crisis: The wreck of the VOC ship Batavia(1629), in *Natural Disasters and Cultural Change*,(ed)Grattan, J., Torrance, R., Routledge, London and New York, (2002), pp. 66-87.

[53] Leach, J., *Survival Psychology*, Sydney (1994)

Detailed study of the hull indicated a poor construction of the ship with the asymmetrical shape of the hull, which resulted in more weight on one than on the other side of the hull.[54]

There are numerous archaeological evidence from this phase of shipwrecks that can be used in attempt to reconstruct the events. Noteworthy and frequent maneuver, which mariners often used before or after the ship accident, was "the ejection of anchors" as a try to slow down or stop the ship. (Gibbs 2006)

3.1.3.2. THE IMPACT PHASE

This fase involves all actions that may be taken by the crew members in response to a direct threat or as a result of the collision of the ship prior to its sinking. In this case, they primarily refer to the actions aimed at repairing the damage of the ship construction, which is caused by direct impact or because of damage caused by war activities. In addition, the actions that may be taken are intentional discharge of cargo or equipment from the deck of the ship in order to decrease the weight or eliminate combustible materials in case that the ship was affected by fire. (Gibbs 2006)

3.1.3.3. RECOIL PHASE

This fase occurs immediately after the shipwreck event and that is the stage in which rescue takes place along with the provision of shelter and safety for the crew and ship's equipment which is necessary for basic survival. This phase is followed by the Rescue phase during which a rescue operation of the ship's cargo and equipment is organized. (Gibbs 2006)

[54] Laursen, L., Vasa's Curious Imbalance, Archaeology, *Archaeological Institute of America, vol.65. 4,* (2012), pp. 42-48.;(http://lucaslaursen.com/vasas-curious-imbalance/)

3.1.3.4. THE FINAL STAGE

Finale stage of the process of formation of underwater archaeological sites is the post-disaster phase in which there is the impact of natural processes. The result of these influences is a state of balance between shipwrecks and external environment.(Ward, 1999) However, the cultural phase of formation of sites continues during this sub-phase, including various types of human interaction, especially organized but also illegal attempts to rescue the cargo and equipment, which can also cause serious damage to the ship's structure.

It is worth noting that often there are cases of dislocation or complete removal of the ship remains where they are located on the waterway and represent a potential danger to navigation.

Gibbs has made a great contribution to the study of the formation of underwater sites, especially in the study of cultural factors and processes that influence the formation of the site. However, it is evident that Gibbs gave a very little attention to unintentional human impact. Stewart in his study of cultural influence, gave a special attention to the unintentional processes including construction of facilities (ports, bridges, oil platforms, pipelines, cabling), as well as the disposal of waste material into the sea. He also devoted a lot of attention to Illegal treasure hunting and sporting and recreational diving within the underwater archaeological sites without protection. [55]

[55] Stewart, D., Formation Processes affecting submerged archaeological sites: An overview, *Geoarchaeology: An International Journal 14.6*, (1999), pp. 565–587.

4. THREATS AND CAUSES OF THE DECAY OF ARCHAEOLOGICAL MATERIAL

Underwater environment provides very good conditions for the conservation of archaeological material that in exceptional cases may be preserved for a very long time. However, shipwreck and other underwater archaeological remains are exposed to many influences that can lead to their decay and final destruction. In order to provide the best protection and conservation of these sites is of great importance to posses the knowledge of the natural environment and all the processes that cause deterioration of a wood or metal ship construction and other archaeological finds.

The main factors causing the deterioration of wooden, organic, and metallic materials can be divided into two groups; (1) natural and (2) Human (Cultural) impact.[56] The natural effects are all mechanical, biological, and chemical processes that influence the degradation of the material and its decay. The human factors consist of all intentional and unintentional human activities that can cause tremendous damage or destroy archaeological sites. It is important to realize that, these processes are not mutually exclusive, and that they mostly operate to interact.[57]

[56] Schiffer, M., (1987). *Formation Processes in the Archaeological Record*. Tucson, pp. 25-47.

[57] Gregory, D., Assessing the burial environment and deterioration of organic archaeological materials, *SASMAP Project*, pp.16-24.

4.1. NATURAL PROCESS

4.1.1. MECHANICAL CAUSES OF DAMAGE (PHYSICAL-MECHANICAL)

Several natural mechanical factors may cause damage to archaeological materials such as ocean currents, waves, natural disasters, and the impact of animal organisms. In addition, important mechanical factor that can have a big impact on the preservation of archaeological material is ice. However, although this factor is very important at high latitudes, it will not be considered because there is no greater influence in the Mediterranean.

4.1.1.1. CURRENTS

The main feature of the physical and mechanical factors is the movement or removal of items and materials from the archaeological shipwreck site due to high-energy hydraulic forces caused by water currents. Because of this influence, the archaeological material on the seabed could be exposed to greater or lesser degree condition the material degradation.

Marine currents have a great impact on submerged archaeological sites, not only because of the abrasive action, but also because of the ability to change the topography of the seabed. Depending on their intensity, sea currents could potentially transmit large quantities of gravel, sand and fine sediment. Transport of sedimentary material creates an abrasive effect that causes the damage of all objects lying unprotected on the sea bottom.

Even at very low speed of water mass, that effect will cause deterioration of wooden residues that have, due to a long stay in the submerged environment and due to biological influences lost their original strength.[58]

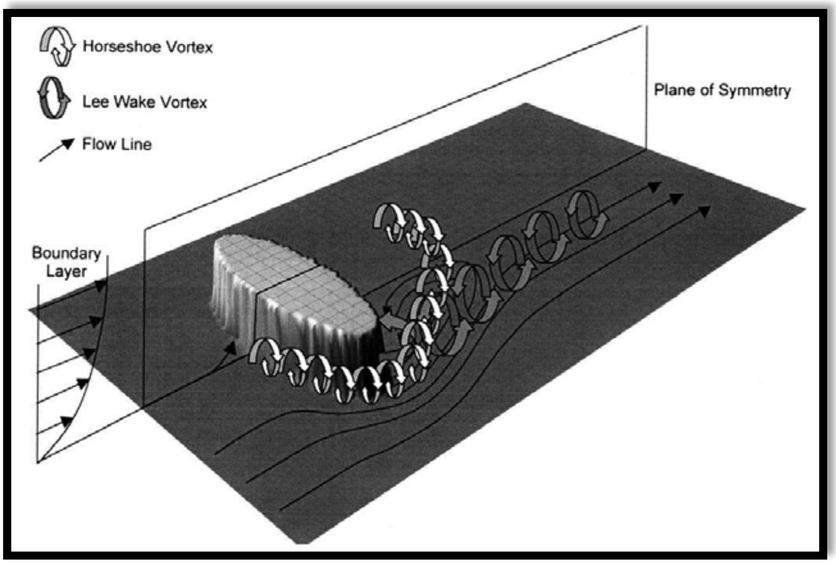
[58] I. A. K. Ward;" A New Process-based Model for Wreck Site Formation". *Journal of Archaeological Science 26,* (1999), pp. 561–570

It is important to note that the transport and deposition of sedimentary material is directly related to the energy of sea currents that can bring about the creation of sedimentary layers but also on its removal. In the first case, the deposition of sedimentary material will have a positive impact on the conservation of archaeological materials in a manner that a sediment layer provides a physical protection of marine structures and other archaeological materials from the negative physical and biological effects of the environment.[59]

In the second case, forces of the water current will cause a negative effect of vortex currents generated around objects and objects on the seabed. (Picture 4.1) These local currents cause strong erosion effect and they can eventually completely remove sediment deposits, or at least a limited part of it, leaving the shipwreck unprotected and exposed to negative physical, biological, and chemical influences. [60](Picture 4.2)

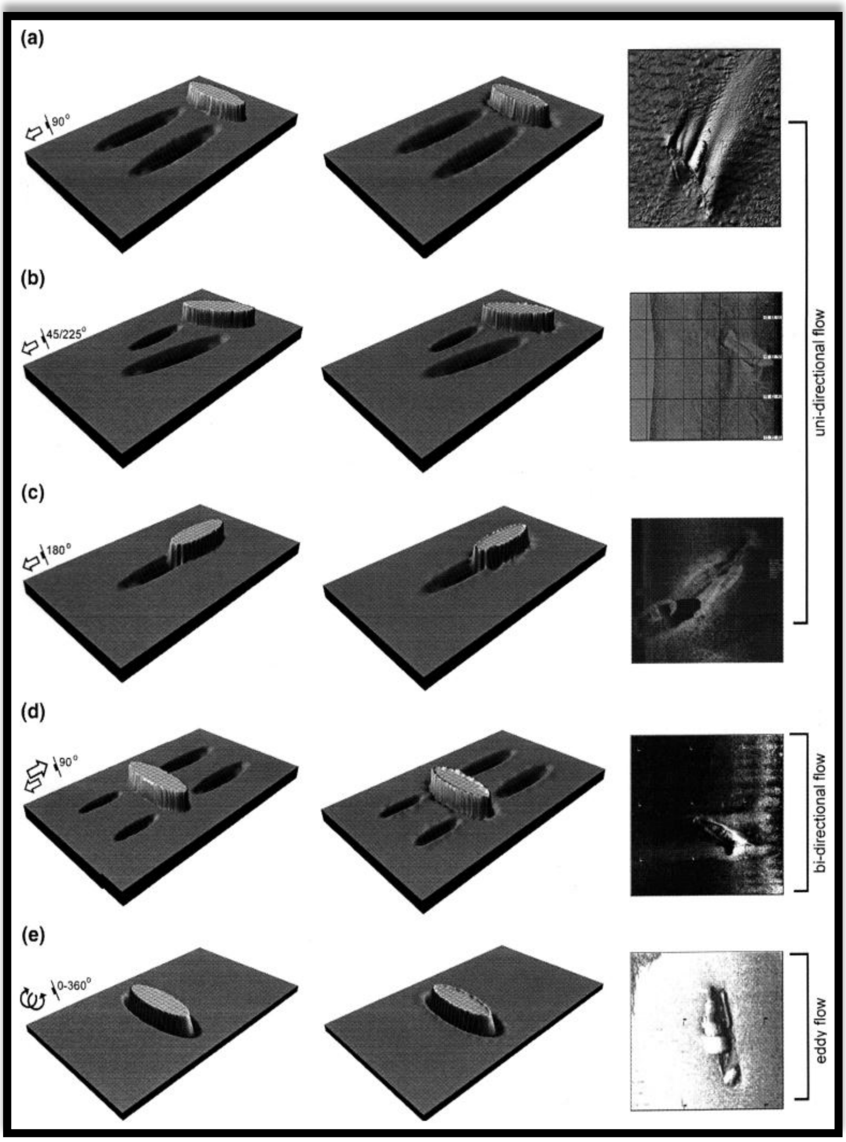
[59] Ward, I., Lacombe, P., and Veth, P., Towards new process-orientated models for describing wreck disintegration, *Bulletin of the Australian Institute of Maritime Archaeology 22,* (1998), pp. 109–114.

[60] R. Quinn; "The role of scour in shipwreck site formation processes and the preservation of wreck-associated scour signatures in the sedimentary record e evidence from seabed and sub-surface data". *Journal of Archaeological Science vol.3*, (2006), pp. 1419-1432



Picture 4. 1 Creating model of local vortex water currents around of ship remains on the sea floor caused by running water masses. The negative effect of these currents is the removal of sediment from the site(R.Quinn 2006)

Waves and currents have a very important impact on the degradation of shipwreck construction and archaeological materials, and the energy of their constant activity is very high and can cause drastic perturbation of the seabed in shallow areas at to a depth of up to the over-20m. With increasing depth, hydrodynamic energy decreases and at depths of 40-50 meters it is generally low enough that it, virtually, has no greater impact on archaeological remains. There are exceptional cases where the currents are extremely strong at much greater depths, but such cases are very rare. Bearing in mind that the depth is only one factor affecting the conservation, at greater depths there are some other influences primarily biological, that play much more important role. It is also important to note that the hydrodynamic energy of marine currents and sea waves can be additionally reinforced by natural disasters (storms, hurricanes...), when the wider coastal zone may be exposed to their destructive influence.



Picture 4.2 Photograph showing the possible models of erosion that can occur due to water currents around shipwrecks to underwater archaeological site in terms of continuous or intermittent flow. The last column shows examples of the acoustic technique of scanning the seabed for a better understanding of how large the effect of water currents may have on the underwater archaeological site. (Quinn, 2006)

4.1.2. BIOLOGICAL THREATS

As one of the most resistant organic material in nature, the wood may be preserved for a very long time in the most diverse cold, dry, wet, or underwater anaerobic environments.

Wooden material, including archaeological materials from wood, in the marine environment is constantly exposed to external influences, and the state of preservation depends largely on local conditions. Factors such as marine and ocean currents, the amount of oxygen, salinity, and sediment are key factors in determining the biological degradation of wood.

Wood is mostly made up of cellulose, hemicellulose, and lignin giving it excellent strength and abrasion resistance. At the same time, these organic materials are an important source of food and energy for a variety of living organisms.[61]

For this reason, over time many different macro and microorganisms are, gradually colonizing wooden residues in the aquatic environment. Some of these organisms use wood as a surface for colonization and settlement and have no harmful effect. In most cases, the organisms that inhabit the wood are parasites that inhabit wood eating it, which leads to its degradation. These parasites have been the major problem since the earliest days when man began to build wooden structures at sea and various wooden boats.[62]

The most famous and certainly the most dangerous species of mollusks and crustaceans, which are responsible for the degradation of wood, belong to the families, of “Teredo" (family Teredinidae) and Gribbles (family Limnoridae). In favorable conditions, these macro-organisms are able to rapidly colonize wooden material and in extremely short period of time cause deterioration

[61] Hedges, J. I., The chemistry of archaeological wood, in *Advances in Chemistry Series,* (ed.) Rowell, R.M.; Barbour, R.J. no. 225,(1990), pp. 111–140.

[62] Bjordal, C. G., & Gregory, D.. *Decay and protection of archaeological wooden shipwrecks.* (2011), pp. 7-10

or complete destruction of the wooden structures and archaeological information.[63]

In addition, microorganisms such as fungi and bacteria can settle the substrate surface and could cause its degradation. The reason for this is that the wood is a mixture of different types of sugars (cellulose) and lignin, which are a rich source of nutrients that these microorganisms feed on. The impact of these organisms is not as aggressive as it is the case of Teredo and Gribbles and degradation is much slower, but still serious enough to lead to drastic damage and decay of wooden structures.

[63] D. Gregory, P. Jensen, K. Stratkvern, T. Lenaerts & M. Pieters. A preliminary assessment of the state of preservation of the wreck of the Belgica , *Relicta 7* (2011), pp.145-162

4.1.2.1. MICROORGANISMS

4.1.2.1.1 TEREDO NAVALIS LINNAEUS, 1758 (MOLLUSCA, BIVALVIA, TEREDINIDAE)

Teredo is a kind of seashells, mollusks belonging to the family Teredinidae. In nature, there are 65 different types of Tredinae, but the most famous and most dangerous Teredo Navalis Linnaeus, 1758 (Mollusca, Bivalvia, Teredinidae), also called “Cosmopolitan” because of its large presence in different parts of the world. Its second name is “Shipworm” because its appearance resembles a worm. At the front end it has a shell that is adapted for drilling of wood. These organisms are *xylophages* and represent the most dangerous and most destructive group of wood parasites that lives in the sea. Creating channels T.navalis inflicts tremendous damage to the ship structures in the sea and potentially is the most threatening to archaeological cultural heritage.[64]

Teredo Navalis has elongated, worm-like body of a reddish color and it is completely enclosed in a tunnel, which it creates in the wood at the bottom of the sea. At the front of the body, it has two calcareous plates up to 2 cm long used for drilling of wood and creating tunnels of circular cross-section of the length of up to 60 cm. These tunnels are covered with limestone mass that worm ejects from its body while eating and living in wood. At the same time, these tunnels are an ideal shelter for T.navalis. (Gregory, D., 2011)(Picture 4.3)

[64] Gregory, D., *Guidelines for predicting decay by shipworm in the Baltic Sea* , Wreck Protect, (2011), pp. 11-17

Picture 4.3 Foto 1. T.Navalis; Foto 2. Heavily damaged the wooden structure due to the activities of T.Navalis

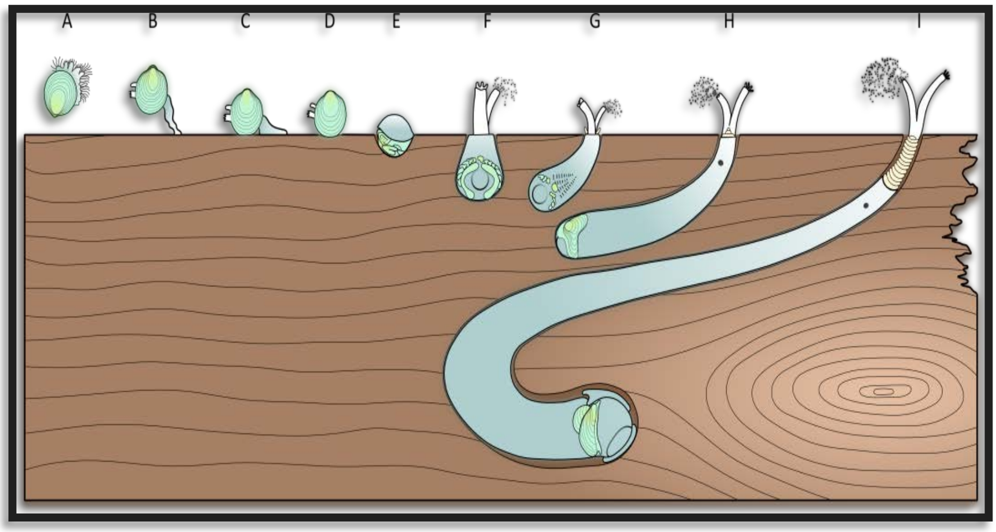
The moment when the presence of T.navalis it discovered, it means that the wood is in an advanced stage of degradation, where the structure of the wood is heavily damaged and that almost any attempt at rescue will be unsuccessful.[65] (Picture 4.3)

The colonization of the wood starts while T. Navalis is in its the larval stage, is the size being 0.25 mm. During this period, the staple food of the larvae T.navalis represents plankton. After the period of 10-14 days, which depends largely on the natural environment, T.navalis reaches its mature stage, when it is ready to settle in wood.

In this period, the tiny larvae have a period of up to two weeks to find a wooden surface, where they would stay, otherwise they will not survive.

[65] Didžiulis, V., Teredo Navalis, Invasive Alien Species Fact Sheet , NOBANIS -Online Database of the North European & Baltic Network on Invasive Alien Species.(www.nobanis.org) (2011), pp.2- 9

Where the larvae penetrate into the interior of the wood there is a very small hole, just one millimeter wide, but over time the channel's width increases as Teredo grows. The moment T.navalis settles in wood, it stays there until the end of its life cycle that lasts 2-3 years, which mostly depends on living conditions.[66] (Picture 4.4)



Picture 4.4 The figure shows the life cycle of Teredo Navalis

Teredo Navalis mainly inhabits temperate and tropical seas and oceans around the world. Because of its wide distribution, it is very difficult to determine the place of its origin. It is mostly spread in coastal zones where can be found a greater amount of disposable wooden materials can be found that the worm inhabits and on which it feeds. The key environmental factors that influence the physiological and ecological behavior of T.navalis are; salinity, water temperature, dissolved oxygen, sea currents and the availability of wood. The presence of T.navalis depends on all these factors. It is important to note that these factors may be variable and depend largely on the seasons. Also possible are certain fluctuations that are associated with the cyclic annual changes.

[66] Castagna, M., *Shipworms and Other Marine Borers*,(1995), pp.7-12

On the other hand, the distribution will mostly depend on the geographic conditions that determine the climatic factors, that will, in a greater or lesser extent, help T.navalis.

These natural conditions may also affect the genetic variations that will cause increased ability of tolerance to various environmental parameters and consequently better adaptability to an inhospitable environment. The best example of this claim, is T.navalis from the Baltic and the North Sea, which showed a very great ability to adapt to a very different and unfavorable living conditions.

Salinity is very important factor that determines the development and distribution of T.navalis. This organism can be found in salt water and tolerates salinity of 5-30 ‰. In previous studies, an opinion was considered that T.navalis live only in salt water. Yet recent research suggests that the T.navalis very often can be adapted to water with low salinity. An example of this represent the North and Baltic Seas, which have a lower salinity compared to the Mediterranean. Despite the low salinity, which is at the lower limit of tolerance for T.navalis, there were several mass phenomena of Teredo Navalis in the Baltic in 1930.and 1950. It can be concluded that the mid-to low-salinity does not provide an ideal place for settling Teredo. This means that their presence will be much lesser so the wooden materials have a greater chance of being preserved for a longer period of time. Yet even in such a relatively unfavorable conditions, T.navalis showed remarkable adaptive abilities.[67]

The temperature range favorable for to the colonization of this organism is very broad. For this reason the ambient temperatures on sites populated with T.navalis could vary from 1°-30 °C. However, these extreme conditions adversely affect their growth and reproduction. The ideal temperature best suited for the development and reproduction of this organism is within the average annual temperatures range between 11°-25 °C.

[67] Gregory, D., *Guidelines for predicting decay by shipworm in the Baltic Sea* , Wreck Protect, (2011), pp, 11-17

The presence of oxygen is certainly one of the crucial factors necessary for the existence of Teredo in a particular environment. It is known that T.navalis can survive a few weeks in environments without oxygen, thanks to its preserved glycogen stores.

However, a longer period without the presence of oxygen will cause its death. In other words, the anaerobic environments that are below the thick and non-porous sedimentary layers are absolutely not favorable for the colonization by Teredo,[68] which is directly related to the potential conservation of wooden materials, because the absence of T.navalis means better and longer natural conservation in-situ.[69]

[68] Elam, M., L., Great Naval Shipworm Teredo Navalis, in Pacific Northwest Aquatic Invasive Species Profile (2009), pp.5-13

[69] Ward, I. A. K.,A New Process-based Model for Wreck Site Formation, *Journal of Archaeological Science, 26,* (1999), pp. 561–570

4.1.2.1.2 XYLOPHAGA DORSALIS

Xylophaga dorsalis is a mollusk of the family Xylophagidae and is one of the best-known types of marine wood parasites. The armor of X. dorsalis has lost its role of protecting the soft body and it became a specialized tool for cutting and digging by which it penetrates into the wood in which it inhabits and feeds on. (Picture 4.5) Wood from the seabed provides a large quantity of nutrients and for this reason this type of mollusk rapidly colonized it. Although there are many similarities with T.navalis, peculiarity of X.dorsalis is that it colonizes both shallow coastal zones and zones of medium and large depths. It is important to note that this organism, although very similar, very rarely shares the habitat with T.navalis.[70]The common characteristic of these two groups of mollusks is that they have symbiotic bacteria are in their digestive system kept symbiotic bacteria that help them digest wood.[71]

Picture 4.5 Xylophaga Dorsalis

[70] Bienhold ,C., Ristova, P., Wenzhöfer, F., Dittmar, T. , Boetius, A. ,"How Deep-Sea Wood Falls Sustain Chemosynthetic Life", in *PLoS ONE 8(1)*, January (2013), pp.1-17

[71] Borowski, C., Nunes-Jorge, A., Symbioses in wood-boring bivalves, in Max Planck Institute for Marine Microbiology, (2014), pp. 1-4

X.dorsalis can be found mainly in dense groups, but it can sometimes be found in small numbers or even individuals can be completely isolated. It is particularly common in the cases where this mollusks inhabits greater depths. This characteristic can be caused by a problem related to its reproduction. For this reason, X.dorsalis has developed a special system of reproduction very similar to T.navalis. This implies that these organisms are always male in early stages of their life. Over the time, as they grow, they gradually change sex to female , while preserving reproductive material necessary for self-fertilization. [72]

4.1.2.1.3. GRIBBLE (LIMNOFORIA LIGNORUM)

Gribble belongs to one of 56 types within Limnoridae Isopoda family. It inhabits mainly the waters of the North Atlantic, the Pacific and the northern zone and the Baltic Sea. After T.navalis, this is the second most aggressive species that attack wood, and is able to inflict great damage to wooden materials. The most famous and most dangerous Gribbles are Limnoria lignorum (Picture 4.6), L. tripunctata and L.quadripunctata.

Picture 4.6 (foto1) Gribble Limnoria lignorum; (foto2) The degradation of wood material caused by the colonization of Gribble Limnoria lignorum

[72] Gregory, D., Guidelines for Protection of Submerged Wooden Cultural Heritage, including cost-benefit analysis, WreckProtect (2011), pp.19-25.

Gribble (Limnoria lignorum) grows to the maximum length of 5 mm. Although very small in size, it can be present in large numbers. Unlike T.navalis, which penetrates into the depth of a wooden structure, Gribbles attack only the surface of the wood creating tunnels of 1-2mm in diameter and several inches long. After the superficial layers of wood are destroyed, gribbles continue the destruction towards the deeper layers.

L. Lingnorum feeds on wood excavated from the channel because it has enzymes that allow it to digest linin, unlike other types of parasites which feed on wood that have bacteria in their digestive system that helps in dissolving cellulose and its digestion.[73]

Reproduction of this organism occurs in the way that a the female keeps the eggs beneath her thorax. After the eggs hatch, miniature copies of adult specimens are immediately able to colonize wood. Ambient temperature plays a very important role in the reproductive process, and young individuals develop significantly faster in warmer conditions. (Daniel, Nilsson, & Cragg, 1991)

The range of water depth suitable for inhabitation varies from coastal shallows to depths of 20 meters. Although Gribbles inhabit colder seas and oceans, this parasite can sometimes be found in warmer seas. Certainly, this organism, although not present in the Mediterranean area, deserves attention because of the devastating effect that it has on wooden structures.

[73] Daniel G., Nilsson T., Cragg, S; "*Limnoria lignorum* ingest bacterial and fungal degraded wood". *Holz als Roh- und Werkstoff vol.49 (12)*, (1991), pp.488–490.

4.1.2.2 MICROORGANISMS (FUNGI AND BACTERIA)

In addition to the very invasive colonization and degradation caused by macro-organisms such as T.navalis, X.dorsalis, L.lingnorum that are the most important representatives of the organisms in underwater organisms that cause the decomposition and degradation of wood, we should not neglect the constant slow degradation caused by microorganisms. A very large number of different types of microorganisms can compromise wood, and the most important types of these groups are fungi and bacteria.[74]

Unlike the macro organisms, micro-organisms are able to degrade wood in the most diverse environmental conditions, bearing in mind that some of these organisms have shown remarkable tolerance to very diverse environmental conditions (presence of oxygen, temperature range, humidity and pH value). Generally, bacteria showed greater ability to adapt to conditions that are considered extreme, which are and at the same time that is less conducive to the development of the majority of fungi and simultaneously absolutely exclude the presence of macro-organisms.[75]

In anaerobic conditions, or where is present a very small amount of oxygen is present in the deep seas and ocean depths, below the mud or thick sedimentary deposits, as well as in conditions of extreme (low or high) temperature, bacteria are the only organisms that lead to degradation and decomposition of wood.[76]

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[74] Blanchette, R. A., Nilsson, T., Daniel, G., Abad, A., Biological degradation of wood, in *Archaeological wood: Properties, chemistry, and preservation,* ed. R. M. Rowell and R. J. Barbour. Advances in Chemistry series 225. Washington, D.C.: American Chemical Society. (1990), pp.141–174.

[75] Y.S.Kim,A.P.Singh;„Micromorphological characteristic of Wood Biodegradation in Wet Environments“, *IAWA Journal, Vol. 21 (2),* (2000), pp. 135–155

[76] Charlotte Gjelstrup Bjordal, Nilsson, T., Reburial of shipwrecks in marine sediments: a long-term study on wood degradation, *Journal of Archaeological Science 35* (2008), pp. 862-872

Up to 50'of the last century, sea bottom, especially at great depths, was considered to be a flat, uniform in biological terms uniform and sterile environment.

This opinion prevailed precisely because of the fact that such places are at a great distance (depth) from the surface without the presence of light necessary for photosynthesis under very high hydrostatic pressure and at very low temperatures which are not favorable for living organisms.

The reality is quite different and the seabed is the most diverse environment that consistently receives organic substances from the surface, as well as the remains of dead animals (fish and mammals), wooden materials, and algae. Depositions of organic materials, the geological processes that help in its distribution, as well as chemical energy, create a specific ecosystem with enough energy required for colonization of microorganisms.[77]

Researchers conducted after the 1950s and in 1960s, which dealt with the analysis of marine sediments at large marine and ocean depths, showed great presence of different types of bacteria. These results led the researchers to conclude that the extreme conditions prevailing at great depths, are not an obstacle to colonization and the normal functioning of certain types of microorganisms.[78]

These and other studies have contributed to the increased interest of archaeologists in the process of degradation of wood in the underwater environment and water saturated terrains in order to develop methods for the preservation and conservation of wooden material of cultural and archaeological interest.[79]

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[77] Jorgensen,B.,B., Boetius,A., Feast and famine-microbial life in the deep-sea bed, *Nature Reviews/Microbiology, vol.5,*(2007), pp.770-781

[78] Zobell, C. E. & Morita, R. Y., Deep-sea bacteria, in *Galathea Report Vol. 1*, (Danish Science, Copenhagen, (1959), pp.139–154

[79] R. M. Rowell and R. J. Barbour, Archaeological Wood-Properties, Chemistry, and Preservation, *Advances in Chemistry series 225*. Washington, American Chemical Society. (1990)

4.1.2.2.1 FUNGI

Fungi that feed on the wood called lignicolous fungi, and are divided into three major groups; Ascomycetes, Basidiomycetes and Fungi imperfecti. Ascomycetes and Fungi imperfecti are far more diversified and more numerous. Basidiomycetes have fewer representatives in relation to the previous two groups, but they are certainly very widespread in nature.[80]

Fungi feed on the wood in a variety of ways: degrading linin (lignin) or carbs (carbohydrates). In most cases, examples of fungal degradation of of wood are characteristic and easily recognizable. However, in some special cases, should be paid attention because it is not always easy to recognize a particular type of fungus because method of degradation method of wood can be very similar.

Ascomycetes and Fungi imperfecti species of fungi decompose wood in a characteristic and a different way in comparison to the kind of Basidiomycetes. The first two groups cause by the so-called Soft-rot degradation of wood, while the third group causes the so-called White-rot degradation. Among the most famous representatives of the Basidiomycetes group of parasitic fungi that inhabit the wood and cause its decay and decomposition are Brown and White rot fungi (Basidiomycetes).

Brown rot fungi degrade the polysaccharide components of wood and leave lignin structure completely undamaged. In contrast to this fungus White rot is able to degrade all the components of the cell wall and the intensity of the decomposition of lignin, cellulose and hemicelluloses varies depending on the kind of White rot. Soft rot erodes the secondary wall of cell membranes and forms a miniature cavity.

[80] Björdal, C.G., Evaluation of microbial degradation of shipwrecks in the Baltic Sea, *International Biodeterioration & Biodegradation 70*, (2012), pp. 126-140

One of the main features is that each type of fungal decomposition and degradation of wood takes many forms and each can be visible and analysed during microscopic observation.[81]

4.1.2.2.1.1 WHITE ROT AND BROWN ROT

White rot fungi belongs to the species of fungi Basidiomycetes, and they are very widespread in nature, predominantly in forest ecosystems. They mostly inhabit surface of mostly dead trees and cause their degradation.

The main characteristic of this type of fungus is that it is able to degrade all components of the cell structure of the wood. Some species of this type of fungi are specialized for the degradation of lignin and hemicellulose only, while leaving cellulose largely untouched. Degradation of wood caused by White rot is recognizable by the formation of erosion of cell wall that is visible under a microscope. This peculiarity is what distinguishes this type of fungus from other types of microorganisms. In addition to these features, White rot has the ability to "whiten" a tree that is also a sure indicator that the wood is attacked and colonized by this fungus.

Brown rot, as well as White rot fungi belongs to the species Basidiomycetes. These fungi also inhabit the forest ecosystems, but it is very often present in other areas, primarily in the underground environment. One of the most important characteristic of Brown rot is degradation of polysaccharides and cellulose. Lignin may also undergo significant chemical modifications. In most cases, lignin can remain intact but in cases of severe degradation, a significant amount of this component can be destroyed. Such degraded cell walls become very porous, but still keep their original shape of cell. The result of the Brown rot fungi attack is the total destruction of the interior cell structure and its basic ingredients.

[81] Blanchette, R. A., Nilsson, T., Daniel, G., Abad, A., Biological degradation of wood, in Archaeological wood: Properties, chemistry, and preservation, ed. R. M. Rowell and R. J. Barbour. *Advances in Chemistry series 225.* Washington, D.C.: American Chemical Society. (1990), pp. 141–174.

On that occasion there comes to partial or complete degradation of cell wall whereby wood loses its structure and the strength and the effect of decomposition wood is very pronounced.[82]

Bearing in mind that these fungi belong to the species of fungi Basidiomycetes, they cause the degradation of wood mainly in dry environments or below the earth surface. The main prerequisite for the presence of these fungi are adequate conditions, which imply certain humidity and the presence of oxygen.

Brown and White rot are very tolerant of the amount of oxygen and its presence can be extremely reduced to a certain limit. However, it is very important to note that these microorganisms will not tolerate underwater anaerobic environment. For this reason, we can say that these types of fungi do not have a significant role in the degradation of wood in an underwater environment. However, due to their prevalence in nature and the great potential for degrading and dangers posed to preserved archaeological material, these fungi are extremely important.

4.1.2.2.1.2 SOFT ROT

This type of fungus is widespread in nature, and it belongs to a group of aquatic wood decaying fungi for reasons since they live, and reproduce in water. This group was subsequently divided into types (1), which live exclusively in water (2) and those that can inhabit both aquatic and terrestrial environment (the field). For this reason, it is capable of causing degradation of wood in underwater environments waterlogged soil or in the dry earth environment. A very important characteristic of this type of fungus is its presence in the environment, especially in water-soaked or underwater environment, which are not suitable for habitation of Brown and White rot fungi.[83]

[82] Kim, Y.S., Singh, A.P., Micro morphological characteristic of Wood Biodegradation in Wet Environments", *IAWA Journal, Vol. 21 (2)*, (2000), pp. 135–155

[83] S.A.M.Hamed,"In-vitro studies on wood degradation in soil by soft-rot fungi:Aspergillus niger and Penicillium chrysogenum" *International Biodeterioration & Biodegradation,78* (2013),pp.98-102

It is considered to be one of the most flexible and the most aggressive fungi that attack wood and can cause significant damage. Soft rot fungus lives at temperatures between 0 ° C and up to 60 °-65 ° C. Because of these characteristics is ranked among thermophiles. In other words, this is a type of fungus that is able to survive in extreme temperatures (hot and cold) conditions in which other species of fungi could not survive.[84]

This type of fungus can also tolerate extremely low percentage of oxygen. Practically, it is able to colonize and degrade wood in anaerobic environments typical for sea and ocean floor, even under a thick sedimentary deposit.

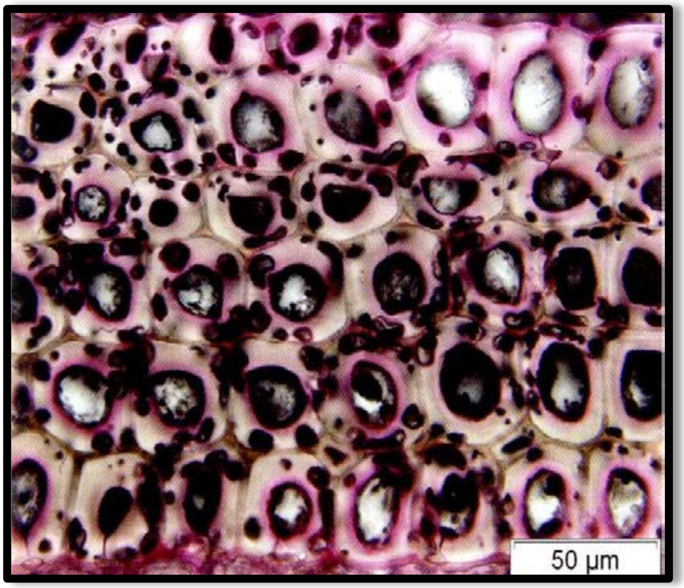
Such conditions are not suitable for settlement of Brown and White rot as well as macro-organisms and their existence in such conditions is absolutely excluded. For this reason, Soft rot can be considered as one of the most important wood decomposers in an underwater environment. In addition to these above-mentioned characteristic, Soft rot is also very tolerant of different levels of ph.[85]

Some of Soft rot fungi can also be found in soil environment and that proves that this type of fungi has exceptional ecological tolerance and is able to adapt to different conditions.[86]

[84] Madigan M.T., Martino J.M. *Biology of Microorganisms,* in Pearson (11th ed.). (2006), pp.136-137

[85] Grattan,D.,W., Waterlogged wood, in Colin Pearson [ed.] *Conservation of Marine Archaeological Objects*, (1987), pp. 55–67;

[86] Björda , C.G., Evaluation of microbial degradation of shipwrecks in the Baltic Sea, *International Biodeterioration & Biodegradation, 70*, (2012) pp. 126-140



Picture 4.7 Typical soft-rot decay viewed in a transverse section of softwood and examined by light microscopy: varying sizes of holes produced by fungal growth in the secondary cell wall (photo: C.Gjelstrup Bjordal)

The most famous and the most aggressive types of Soft rot are Aspergillus niger and Penicillium chrysogenum. These fungi degrad mainly cellulose and hemicellulose, and lignin remains intact. (Picture 4.7)

Defects that are formed during the decomposition are actually superficial damage to wooden structures that occur in two basic forms; (1) creation of a cavity in the secondary wall of the cell structure following the microstructure of cellulose (2) complete erosion and degradation of the secondary cell wall of wood. A.niger is capable of inducing both types of damage and the P.chrysogenum causes erosive degradation only.

It is important to note that very often some of these types of fungi, can be found along with certain types of bacteria that cause decomposition of wood.[87]

[87] Hamed. S.A.M., In-vitro studies on wood degradation in soil by soft-rot fungi: Aspergillus niger and Penicillium chrysogenum. *International Biodeterioration and Biodegradation. 78,* (2013) pp. 98-102.

4.1.2.2.1. BACTERIA

Bacteria are single-celled organisms, which are morphologically primitive compared to fungi, and they make the most important decomposers of organic and inorganic substances in nature. Many studies on the degradation of wood before the 1970's confirmed that fungi had the greatest influence on the degradation of wood and the role of bacteria in this process was considered less important. A research that is most recent, suggests that bacteria are an extremely important factor in the process of decomposition of wood. In addition, they have a much more significant role in the degradation of wood in respect to fungi, and in some specific environments, such as anaerobic environments, they are the only organisms that can lead to decay of wooden materials.[88]

Bacteria are present in nature and populate by the most diverse ecosystems. Their main characteristic is adaptability to the conditions of the environmental conditions that they inhabit. This characteristic allows them to settle even in areas with prevailing extreme conditions. In anaerobic conditions, or where is present a very small amount of oxygen is present, such as sea and ocean depths, below the mud or thick sedimentary deposits, as well as in conditions of extreme (low or high) temperatures bacteria are the only organisms that lead to degradation and decomposition of wood. [89]

Many species of bacteria that inhabit the wood do not use it for food and these bacteria do not represent a great threat to the wooden material. On the other hand, bacteria that can cause great degradation of the wooden materials are those feeding on food. These bacteria are able to decompose lignin and cellulose from the wood cell membranes.

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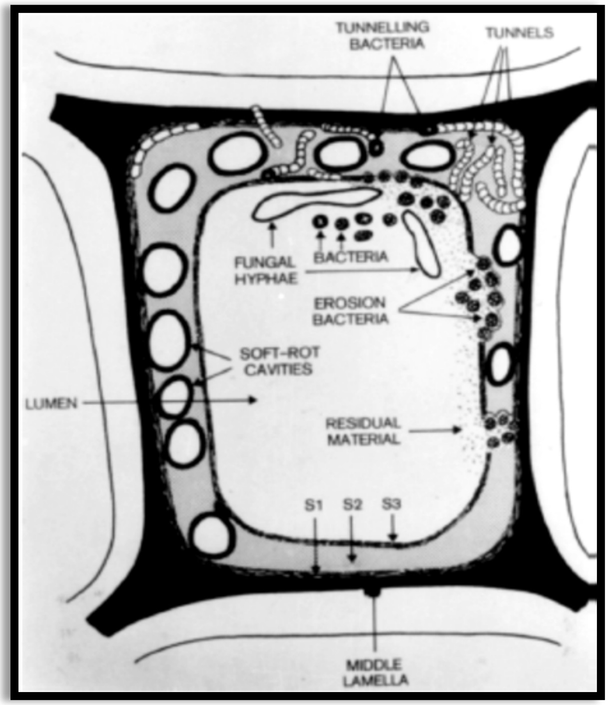
[88] Y.S.Kim,A.P.Singh, Bacteria as Important Degraders in Waterlogged Archaeological Woods, *International Journal of the Biology, Chemistry, Physics and Technology of Wood*. (1996), pp.389-392

[89] Bjordal, C.,G., T.Nilsson „Reburial of shipwrecks in marine sediments: a long-term study on wood degradation“ *Journal of Archaeological Science 35* (2008) pp.862-872

The main representatives of these processes are erosion, cavitation, and tunneling bacteria. They cause several different models of degradation of wooden structures. These models are manifested in the form of surface cavitation, tunnels and erosion, by which these bacterial species were named. (Picture 4.8)



Picture 4.8 Picture shows three types of attacks and the degradation of the cell wall of the wooden structure caused by (1) erosive bacteria, (2) tunneling and (3) cavitation bacteria

4.1.2.2.1.1. EROSIVE BACTERIA (EB)

Erosive bacteria (EB) is the most popular type of bacteria that causes decomposition of wood in underwater or in waterlogged environments and we regard it as one of the most dangerous microorganisms. These bacteria are highly adaptable to the natural environment. They are able to live in areas with wide pronounced temperature range as well as with extremely low level of oxygen, even in areas that are a few tens of centimeters below the sediment layer.[90]

This type of bacteria causes the degradation of cell walls by producing the "channels" parallel to the cellulose fibers visible under a microscope, which results in the creation of surface erosion. This type of wood degradation is characteristic for the colonization and activity of Soft rot fungi. These bacteria colonize the wood very often with of Soft rot fungi. To determine what type of parasite is present, it is necessary to perform morphological analysis. Often the EB colonize wood together with TB, but unlike of Soft Rot fungus, TB causes a completely different type of wood degradation. Another important feature that characterizes the erosive bacteria is that it produces extracellular slime, which allows bacteria to be attached to the wall of cell and is used for their movement. This granular material occurs after the decay of timber and covers the degraded parts of the wood. It is assumed that the decomposition of lignin and polysaccharides has results in the creation of slime.[91]

4.1.2.2.1.2. TUNNELING BACTERIA (TB)

This type of bacteria is also very present in nature and can be found in the earth and in the underwater environment and is able to adapt to the most diverse environment. It is considered one of the important microorganisms that feed on wood and may be very often found together with other microorganisms and usually with EB and of Soft rot fungi. By the manner in which it decomposes wood, TB is quite specific. [92] Unlike EB, which breaks of cell wall of wood, TB dissolves the inner part of the cell wall and creates tunnels that are very characteristic.

[90] Curci, J. “The Reburial of Waterlogged Archaeological Wood in Wet Environments, *Technical Briefs in Historical Archaeology*,(2006), pp.21–25

[91] Björda , C.G., Evaluation of microbial degradation of shipwrecks in the Baltic Sea, *International Biodeterioration & Biodegradation, 70,* (2012) pp.126-140

[92] T. Nilsson, A.P. Singh, Tunneling bacteria and tunneling of wood cell walls“, in McGraw-Hill, *Encyclopedia of Science and Technology,* (2012), pp. 395-399

These tunnels can penetrate all areas of the cell and the direction of the tunnel may be an indicator of the bacteria movement. The degradation caused by TB can be viewed and analyzed using an electronic microscope (TEM) or using a light microscope.[93] This is particularly true for the initial phase of degradation that is still clearly visible, along with all the characteristics of TB activities. In the later stages of this phenomenon it is not easy to see and identify the cause because of the large degree of damage of wooden structures.[94]

4.1.2.2.1.3. CAVITATION BACTERIA

This type of bacteria is less known and explored compared EB and TB, although it certainly is among the more dangerous representatives of wood decomposers. Typical characteristic of this type of bacteria is that it attacks the interior walls and the cellular structure of wood, creating a small cavity on the surface of the wood. At the beginning, the cavities are very small, but later their size significantly increases with the decay of wood, retaining its characteristic shape. In advanced stages of degradation, the cavity can spread until several cavities connect. The results of the expansion of smaller cavities are very large cavities of irregular shape. As well as EB and TB, the Cavitation bacteria produce characteristic mucus. Given its limited distribution, these facts lead to the conclusion that this type of bacteria occurs only in certain situations.

[93] Singh, A. P, Schmitt, U., Electron microscopic characterization of cell wall degradation of the 400,000-year-old wooden Schöningen spears, *European Journal of Wood and Wood Products, 63, 2,* (2005), pp.118-122

[94] Singh, A. P., Role of electron Microscopy, in *Understanding Deterioration of wooden object of Cultural Heritage,* (2000), pp.1-9

4.2. HUMAN IMPACT

Throughout history, man has left behind the most diverse traces as a kind of testimony of its existence and its activities. Cultural and historical heritage of the past can be found in different areas and environments and their existence is recorded on the ground but also under water. The main differences between them are the visibility and availability. For this reason, any destruction or potential jeopardizing of an archaeological site or object of cultural importance in the dry, terrestrial environment, by man or by natural influences is usually visible and cannot go unnoticed. On the other hand, archaeological cultural heritage and shipwreck site under water are hidden and inaccessible to most people. Their destruction by human or natural influences is largely unnoticed.[95]

A man and his (1) unintentional and (2) intentional activities pose a great threat to the underwater archaeological cultural heritage and have a huge impact on their protection and conservation. Unintended activities indirectly endanger the cultural heritage and this group includes mostly large commercial construction works of a different type. Intentional actions are deliberate and planned actions of individuals or different groups, for personal interests and to obtaining material benefits.

[95] Grenier, R., Mankind, and at Times Nature, are the True Risks to Underwater Cultural Heritage, *Underwater Cultural Heritage at Risk*,(2006), pp. 10-15

4.2.1. INDUSTRIAL DEVELOPMENT AND LARGE CONSTRUCTION PROJECTS

Modern human community strives constantly to technological and economic development in order to achieve higher living standards. Large companies and corporations develop and use the most advanced methods and techniques in order to achieve faster and higher global commercial development. The imperative to achieve the highest profits possible, combined with the latest technologies puts an immense pressure on the natural environment and thereby the sea and ocean floor. The rapid development large commercial projects of exploitation of oil and gas, dredging, commercial fishing and fish farms, installing cables and pipes in the coastal areas and the open sea, greatly endanger underwater ecosystems but also the underwater archaeological cultural heritage.[96]

Areas that are most vulnerable are precisely those that are within the territorial waters, in fact 12 nautical miles from the coast. It is precisely this area that is the zone of greatest archaeological potential, but also the area where this potential is at the greatest risk and the most vulnerable. One of the most vulnerable areas is the Mediterranean because of its important geographical position.

[96] Grenier, R., Nutley, D., Cochran, I., Underwater cultural heritage at risk: managing natural and human impacts. ICOMOS-International Council on Monuments and Sites, 2006, pp. 10-15

4.2.1.1. OIL AND GAS EXPLORATION

Oil and gas exploration involves very large and long-term projects that are of great economic importance for countries that have this kind of natural resources. Projects of this type are very complex and multiphase. These include researches and different testing on the bottom of the sea, digging, anchoring and big logistics, and preparation for the construction of oil and gas platforms and pipelines that will drain the oil for further processing. The impact of this project on the environment and on the sea floor is huge and with great long-term consequences. During this work, there is a possibility of endangering or completely destroying plant and animal species in the area that can be brought about by construction works or various perturbations. One should not forget that there is a potential risk of accidents and spills of crude oil into the sea, which are relatively common and leave the direct catastrophic far-reaching consequences for the environment and indirectly for man.[97] These actions have the same effect these actions leave on the underwater cultural heritage, which can be very vulnerable, damaged, or lost forever. [98]

4.2.1.2. THE CONSTRUCTION OF PORT AND MARINE TERMINALS

The construction of port and marine terminals in urban areas, as well as the digging of waterways also represent a potential threat to the underwater environment, shipwreck sites, and for the Underwater Cultural Heritage (UCH) generally. At the same time, these projects are of great importance for commercial development. Human communities of the Mediterranean in particular, but also from other parts of Europe, have traditionally had need to be connect by maritime commercial routes to other cities.

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[97] Ocean Portal, Smithsonian National Museum of Natural History, http://ocean.si.edu/gulf-oil-spill

[98] „Deepwater Horizon accident and response“, http://www.bp.com/en/global/corporate/gulf-of-mexico-restoration/deepwater-horizon-accident-and-response.html

These routes exist today and are extremely important for the countries of the Mediterranean. Yet the economic interests should not endanger other aspects of life of people or areas of special natural or cultural-historical value. In order to achieve a balanced solution and compromise solutions for sustainable development, it would be necessary to carry out several activities in order to protect and prevent shipwreck sites from the destruction.

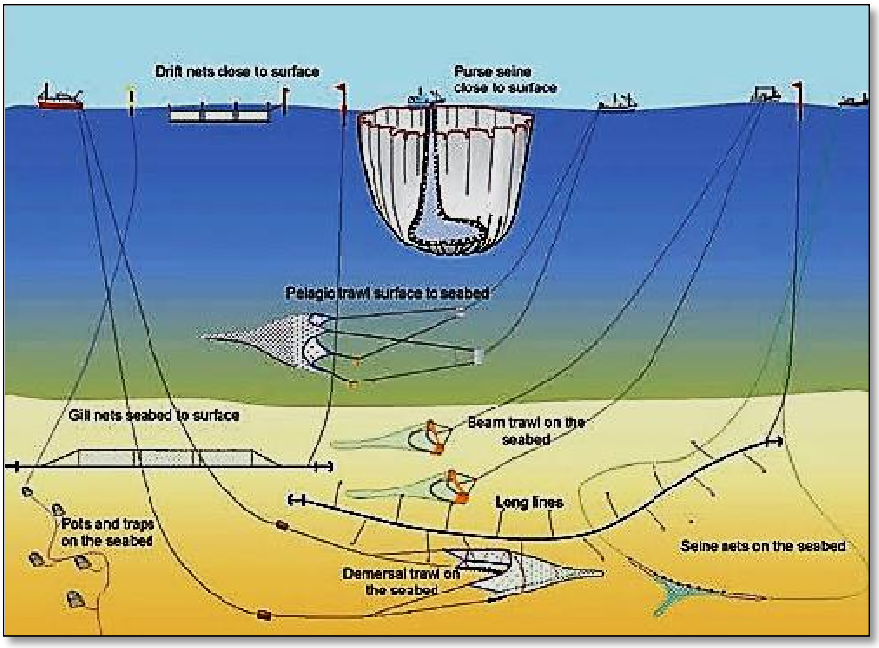
Certainly one of the first actions should be to analyze the wider area of the underwater terrain on which they planned works to identify shipwreck sites. After a detailed analysis of the seabed with modern methods for the detection of archaeological sites and objects of archaeological importance, the entire area of interest should be declared as protected zone. The European project MACHU, based on GIS database program, can serve as a good example.[99] The main objective of this project is to provide relevant information about underwater cultural heritage in the region of Western Europe, accessible to academics, policy makers and for economic development strategies, as well as the public. As a result, subsequent planning and execution of the entire projects would have to be adjusted in accordance with the norms of the Law on Protection of Cultural Property UNESCO.[100]

[99] MACHU Report,(2006-9), nr.1; (www.machuproject.eu)

[100] Convention on the Protection of the Underwater Cultural Heritage, Paris, 2 November 2001.UNESCO.

4.2.3. COMMERCIAL FISHING AND FISH FARMING

Commercial fishing is an economic activity that is involved in hunting fish and other seafood for commercial purposes. It is also defined as industrial fishing. This type of fishing provides a large quantity of food to many coastal countries and enables export trade with other countries that do not have access to the sea. The growing number of the world's population has an increasing need for food and marine products. Techniques and methods of fishing are all inventive and progressive. (Picture 4.9)



Picture 4.9 Graphic of fishing gears in the water column. Ground trawling is a major concern for the preservation of submerged archaeological sites and the environment.(photo UNESCO manual for activities directed at Underwater Cultural Heritage, 2011. pp.270)

Pressure on marine resources is increasing in order to provide the most efficient and successful catch and cash income. The most important fishing techniques in coastal areas are fishing for bottom towing (trawling) and commercial fish farming. (Picture 4.10)

Fishing in tow is certainly the most dangerous fishing method that can potentially threaten most shipwrecks primarily because it is done in coastal areas with the most archaeological sites or objects of cultural value.

The second reason is that this method has an aggressive effect on the seabed. Heavy fishing nets are destroy the seabed, which is habitat for many marine species. In addition, fishing in tow is a non-selective method. Fishing nets captures the incredible variety of animal species and objects, including those of archaeological importance. Dragging heavy nets and other fishing gear over shipwrecks, has disastrous effects on an archaeological site. Due to the dramatic perturbation of the seabed, archaeological material can be destroyed or moved from its place with significant damage.

After that, it is very difficult to complete recognition of the archaeological objects and make a contextual connection to the archaeological site from where the object is moved. This problem is especially evident in the area of the northern Adriatic, where this type of fishing is present. The configuration of the seabed is flat, sandy, and suitable for this method of fishing that has caused severe damage to several underwater archaeological sites.[101]

Picture 4.10 Trawler ship

[101] C. Beltrame, Processi Formativi del Relitto in Ambiente Marino Mediterraneo,(1997).pp.11.

4.2.4. TREASURE HUNTING

Looters, unauthorized explorers, and treasure hunters pose certainly one of the biggest threats to the underwater cultural heritage of the Mediterranean. By definition of the UNESCO Convention on the Protection of UCH in Paris in 2001 treasure hunting is an illegal activity and as such is prohibited in all countries signatories to the Convention.

The main objective of underwater archeology is to gather reliable information and data in order to study human history and activities of the past as well as for the conservation of archaeological material. On the other hand, treasure hunters are not interested in scientific research and conservation of the discovered material. Their main motive is to achieve financial gain and wealth by selling found objects or to create private collections. These two approaches are in direct conflict primarily for ethical reasons and because the discovered archaeological objects can be valuable evidence for archaeologists, necessary for the reconstruction of the past.

There are plenty of examples of various private companies that have found and pulled out from the seabed material of great cultural and aesthetic value. Much of this material was sold on illegal private auctions and its scientific and cultural value is lost forever.[102]

In recent years, there have been several attempts to justify the activity of treasure hunters with the statement that not all campaigns are aimed at the destruction of archaeological evidence, and that they also help saving valuable items, although they are subsequently sold at private auctions![103] There are several reasons why the underwater archeology and treasure hunting are two very opposing approaches and why treasure hunting contributes only destruction of cultural heritage;

[102] Bekic, L., Underwater Cultural Heritage and the UNESCO Convention, *Conservation of Underwater Archaeological Finds Manual*, (Zadar, 2011).pag.7-12

[103] Bowens, A., What is not Archaeology Under Water, in *Underwater Archaeology, The NAS Guide to Principles and Practice*, (2009),pp.6-8

1) The main difference is that archeology deals with the study of existing and acquisition of new knowledge, making it available to a wider audience and each project has the ultimate goal of creating archives and scientific publications that will be available in academic circles and to public,

2) In order to acquire new knowledge, archaeologists use the most diverse and the smallest evidence that have been carefully collected in the field as opposed to the treasure hunters who are interested only in objects of commercial value while destroying everything else,

3) The results of archaeological researches are intended for the future education of scientists staff in the future and to raise public awareness about the values of the Underwater Cultural Heritage.[104] It is very difficult to estimate with certainty the amount of illegal trade involving objects of cultural value. Indeed, recent studies have shown that the theft of underwater cultural heritage in the Mediterranean region and its trade on the black market is much higher than it has been previously anticipated, and that the trend is steadily increasing.[105]

In addition to the unauthorized exploitation of cultural goods, there is a fact that scientific institutions as authorized state institutions dealing with research and protection of cultural goods are often not able to provide the necessary funds for the work. Commercial researchers are therefore a great advantage and are very successful in marine exploration and exploitation. Despite the fact that their projects are funded from private budget, they very often manage to recover money for research, confirming their right to possession and sale of cultural finds excavated from the water.

[104]Bowens, A., What is not Archaeology Under Water, in *Underwater Archaeology, The NAS Guide to Principles and Practice,*(2009),pp.6-8

[105] Pastore, G., The looting of archaeological sites in Italy. Trade in illicit antiquities: The destruction of the world's archaeological heritage. Cambridge: McDonald Institute for Archaeological Research, 2001, pp. 155-160

This approach is in direct conflict with the interests of the scientific community and the public who have an interest in the protection and preservation of cultural heritage.[106]

The conflicts of interests and ethical disagreements have intensified the debate over the ownership and management of underwater sites. The result of this debate is the UNESCO Convention on the Protection of UCH in Paris in 2001.

[106] R. Frost, Underwater Cultural Heritage Protection, *AUST. YBIL 23,* (2004), pp. 23 -25.

4.2.5. SPORT DIVING

The development of diving begins with the technological innovation of Jacques Cousteau and Gagnan who first found and patented apparatus for autonomous breathing beneath the surface of water. From that moment, commercial and sport diving has experienced great expansion.

Today, millions of people have the possibility to independently dive under the water and enjoy the beauty of the underwater world. The existence and availability of sunken shipwrecks and other archaeological remains at the bottom of the sea are a challenge for most recreational divers who are willing to travel halfway around the world to have the opportunity to dive on some of the attractive underwater sites.

It is important to note that the popularization of recreational diving has a positive effect on the Protection of Underwater Cultural Heritage. There are numerous cases where divers have discovered and reported archaeological remains on the seabed. There are also cases of organized sport diving centers in order to monitor and protect the underwater sites. Such centers have a special license from the regional institutions that allow them to be able to lead an organized groups of divers to visit the underwater sites.

Of course, there are always the negative effects of mass visiting and disturbing underwater archaeological sites. First, there is always the problem with the attempts to steal archaeological findings by a diver or an entire group. Basically, the motive for such an occurrence is the collection of souvenirs, although, a often stolen item can have great economic value.

Another negative effect is continuous disturbance of archaeological site. Very often, a diving club which has a commercial license to visit such sites, in order to achieve greater profits, organizes daily a large number of groups and recreational divers to visit the site.

Picture 4.11 Attempt of entry of sport divers in the interior of the ship, often leads to physical damage of ship structures

As a result of the movement of many divers there comes to physical damage of fragile ship structures. This is especially true when divers attempt to penetrate into the interior of shipwrecks.[107] In that case there may occur two main types of damage that can cause permanent damage;(1) direct physical damage caused by contact between divers and of ship remains, (2) creating air pockets.(Picture 4.11)

Human endangering and destruction of UCH, caused by recreational diving is certainly less dramatic compared to other human activities, primarily the large constructional works, exploitation of oil and gas and commercial fishing. Certainly not trivial and for longer periods of time it can cause severe damage.[108] For this reason, it is necessary to make additional efforts by means of existing legal provisions, and the proper education of the public, to raise awareness of the value of the underwater cultural heritage to a higher level, which would also allow for better preservation.

[107] In accordance with Article 7. of the Historic Shipwrecks Act from 1994.,"Divers are prohibited from penetration and entry into the interior of shipwrecks and is considered to be illegal"

[108] Viduka, A., Managing Threats to Underwater Cultural Heritage Sites: The Yongala as a Case Study, *Heritage at Risk*,(2006),pag.61-63

4.3. FINAL CONSIDERATIONS

In nature, there are a numerous factors that can affect the decomposition of organic and inorganic substances, and they represent a great threat to the underwater archaeological sites. Biodegradation of organic and inorganic materials in aboveground dry conditions differs significantly from the decomposition of the same materials in underwater or in water-saturated environments. This is principally related to organic materials, primarily wood. In underwater environment, especially at great depths below the sediment layers, the process of degradation of wood is much slower. The reason for this phenomenon is a highly reduced amount of oxygen or its complete absence in the case of wood being under very thick sedimentary deposits. In addition, the extremely low temperatures are a limiting factor that slows down the process.[109]

Under such conditions, the destructive impact of extremely aggressive representatives of macro-organisms is reduced to a minimum. Examples are T.Navalis, Gribble (Limnoria lignorum) or X.Dorsalis which are typical aquatic organisms with common characteristics that they have a remarkable ability to adapt to environmental conditions.

However, in most extreme cases, when the wood is in an anaerobic environment, is absolutely excluded the impact of these organisms, given their need for a minimum amount of oxygen. Under such conditions, the destructive impact of extremely aggressive representatives of macro-organisms is reduced to a minimum. Examples are T.Navalis, Gribble (Limnoria lignorum) or X.Dorsalis which is a typical aquatic organisms with common characteristics that have a remarkable ability to adapt to environmental conditions. However, in most extreme cases, when the wood is in an anaerobic environment, it is absolutely excluded the impact of these organisms, given their need for a minimum amount of oxygen.

[109] Kim, Y.S., .Singh A.P., Micro morphological characteristic of Wood Biodegradation in Wet Environments, *IAWA Journal, Vol. 21 (2),* (2000), pp. 135–155

A similar situation is also in the case of microorganisms. Destructive influence of some widespread and extremely aggressive microorganisms in dry ambience as White Rot and Brown Rot Fungus in underwater and anaerobic conditions is very limited or completely impossible.

Recent studies have shown that erosive and tunneling bacteria and Soft rot fungi, play a major role in the degradation of wood[110], in extreme conditions such as on the seabed and below sea sediments, [111] unlike previous researches which claimed that bacteria and fungi in particular cannot be an important factor in the degradation of wood in marine conditions.[112]

Series of scientific papers by Bjordal C.G, Nilsson T. (2000.2012), R..A.Blanchette, P.Hoffmann(1993) and Mouzourás et al. (1986) were aimed to identify and examine the presence of micro-organisms that cause deterioration and degradation of wood at various locations in underwater and water-saturated environments and to determine the effect and degree of damage which they cause.

Wood that has been used for examination was found at different archaeological sites, and was of different origin and type. In majority of cases the wooden samples had severe morphological damage. A detailed morphological analysis in all cases revealed the presence of erosive and tunneling bacteria and also of Soft rot fungi, which were the main causes of degradation. This analysis also showed that the erosive bacteria have been found in samples of wood that lay beneath a thick sedimentary layer of 10-42cm and was most active in this environment.

In similar conditions, there were found and tunneling bacteria and Soft rot fungi, which have also shown the ability to live and be active under

[110] Bjordal, C., Nilsson, T. (2002). Waterlogged archaeological wood—a substrate for white rot fungi during drainage of wetlands. *International Biodeterioration & Biodegradation, vol.50,* pp. 17-23.

[111] Kim, Y., & Singh, A. (1996). Bacteria as Important Degraders in Waterlogged Archaeological Woods. *International Journal of the Biology, Chemistry, Physics and Technology of Wood*, pp. 389-392.

[112] Blanchette, R.,A., Hoffmann, P., Degradation processes in waterlogged archaeological wood, *Proceedings of the fifth ICOM Group on Wet Organic Archaeological Materials conference*, Portland, Maine, (1993), pp. 111-142

sedimentary layers, with the difference that the soft rot fungus was found at a depth of maximum 10cm.[113]

Analogous results were presented in other scientific analysis conducted by Y.S.Kim and his team of associates over the period of 1989-96. year. This research has aimed at analyzing the wooden archaeological materials from the sunken Chinese merchant ships in the Pacific Ocean and the Yellow Sea. Also, in this case was been recorded heavy degradation of wood materials was recorded in several different underwater archaeological sites. The cause of the degradation is primarily Erosion Bacteria, Soft Rot and very often there was, and Tunneling Bacteria present.

It is important to note that all the studies that have been conducted have shown very interesting results in terms of the ways of colonization by microorganisms. It is interesting that in some cases the EB and TB inhabited the wood completely independently, while in majority cases the colonization by Erosion Bacteria, Tunneling Bacteria and Soft rot was simultaneous. Very often the presence of microorganisms has been recorded, together with macro-organisms T.Navalis, Gribble (Limnoria lignorum) and X.Dorsalis.

Nature of the interaction between microorganisms and their symbiosis with macro-organisms is not well known. Some of the recent researchs in the UK waters, have established the presence and simultaneous degradation caused by Gribble (Limnoria lignorum) together with the soft rot fungi and Tuneling Bacteria.

These studies have not yet yielded concrete answers and leave space for the assumption that the activity of the microorganism, in this case, serves for softening the wooden structure. Limnoria also feeds on timber and these organisms so that they can later enable digestion.

This assumption leads to the conclusion that apart from the physical degradation of the wood caused by the action of microorganisms Erosive bacteria (EB), Tunneling bacteria (TB) and Soft rot fungi, their activities also

[113] Bjordal, C. N. (2008). *Reburial of shipwrecks in marine sediments: a long-term study on wood degradation.* pp. 862-872.

lead to the softening of internal and external structure of the wood making it more sensitive to mechanical impacts from the external environment, particularly the erosion due to sea currents and sediment. Indeed, the intensity of degradation of wood mass is much slower compared to macro-organisms, but not negligible, especially if the wood is exposed to the bacteria and fungi for a long time. This may cause a weakening of the strength of the wooden structure, and later, in combination with other influences, lead to total destruction of the wooden material.

As a conclusion, we can say that the macro-organisms and microorganisms are a major cause of degradation of wood materials under water. Degradation of wood material is also present in the layers below the sedimentary deposits and microorganisms are the main and the only factor of degradation in semi-anaerobic environments.[114]

It is important to note that there are other factors that can lead to degradation of archaeological material. Complex formation processes of the archaeological sites are of great importance and can very much contribute to the conservation or degradation of archaeological materials and sites, but in extreme cases they are not essential.

The same goes for certain marine animal species whose activities and actions can cause various perturbations of the underwater terrain and directly or indirectly endanger the archaeological material.

However, given the wide distribution and the representation of the aforementioned macro and microorganisms, it can be said that they are generally the primary factor leading to permanent and constant degradation of archaeological material under water while other effects, although very important, are less important in relation to biological factors.

On the other hand, certainly the largest threat and danger for shipwreck sites and underwater cultural heritage is a man.

[114] Bjordal C.G., Daniel G., Nilsson T., 2000. "Depth of burial, an important factor in controlling bacterial decay of waterlogged archaeological poles". *International Bio deterioration and Biodegradation 45,* 15-26.

Despite numerous legal provisions that exist in developed countries around the world and an extremely large effort to preserve shipwrecks and UCH, underwater archeological sites are unfortunately constantly endangered every day due to human activities.

The total submission to the acquisition of monopoly profits and political power leave the governments of those countries totally blind and they, despite awareness of the endangered environment and shipwreck sites take no action, or at least insufficient actions, in order to protect them. In this way, valuable testimonies and traces of human activities of the past as a unique and non-renewable source of information are permanently damaged or completely destroyed.

5. THE ARCHAEOLOGICAL HERITAGE IN THE MEDITERRANEAN REGION - PECULIARITIES OF THE MEDITERRANEAN AND DIFFERENCES WITH THAT OF NORTHERN EUROPE

5.1 INTRODUCTION

Throughout history, since the original foundation of the earliest human communities, the Mediterranean has always been a dynamic region. Various ancient civilizations were created and developed on its banks. For this reason, the Mediterranean is considered the place where the society, in which we now live, is created.

History of the Mediterranean is a kind of interaction between cultures and peoples who inhabited its shores. Over the millennia and centuries, the borders separating the nations were constantly changing. However, historically speaking, these borders have not been an obstacle, but they often represent a place where different civilizations meet. The Mediterranean Sea has always been a place where people were in constant motion, and the central link that connected nations, and where there was an exchange of ideas, customs, culture, beliefs, and traded goods.[115]

Probably the best definition and answer to the question; “What is the Mediterranean?” was given by Braudel; "A thousand things together… not landscape but innumerable landscapes, not a sea but a multitude of sea. Not one civilization but a series of civilizations stacked chronologically over each other."[116]

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[115] Abulafia, D., *The Great Sea: A Human History of the Mediterranean*, Oxford University Press, (2011),pp.3-42.

[116] Braudel, F., *Il Mediterraneo. Lo spazio e la storia, gli uomini e la tradizione, Bompiani*, Milano, 1987, pp. 7.

The history of the navigation on the Mediterranean region dates back thousands of years ago. Ever since ancient times, the people who inhabited the Mediterranean were skilled sailors. Probably long before, they began to engage in many other activities they were able to navigate over the high seas. Archaeological data that have been found on the Greek island of Melos, demonstrate that the people 11000 years ago came from the mainland to the island in search of obsidian and other mineral rocks that were used for making stone tools and later, 8000 years before our time, sailors who came from the coast of Greece, inhabited the island of Crete and created the ancient Minoan culture.[117]

This culture existed until the end of the second millennium BC. Minoan traders established an ancient navigational route and realized the importance of commercial links with other civilizations in the region, especially with the Egyptian and Phoenician who populated the eastern coast of the Mediterranean Sea, now the coast of Egypt, Lebanon, Syria and Israel.

On the other hand, around the 8th century BC, the Phoenician civilization already established their colonies in the central and western Mediterranean, and further developed the maritime routes and had absolute naval and commercial dominance in the Mediterranean for several centuries.

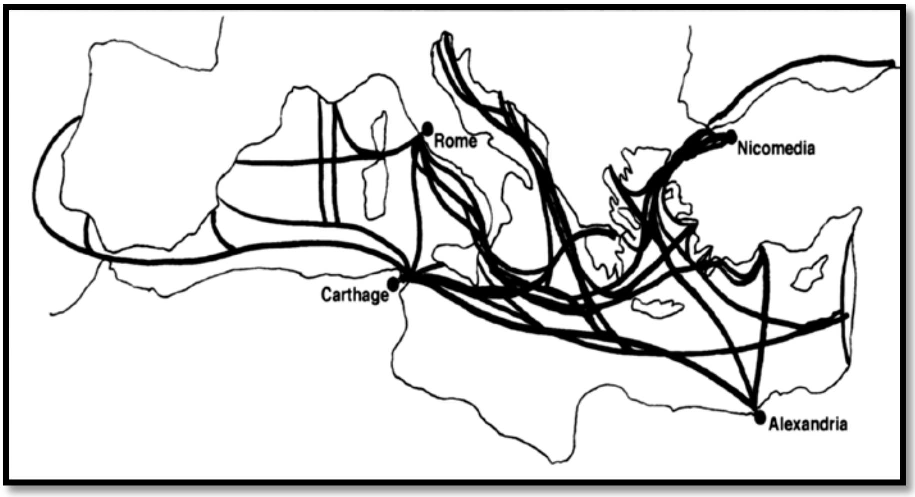
Greek classical culture was fully oriented to life by the sea and on it. Greeks further continued the process of colonization of the Mediterranean by founding many colonies in the Aegean and the Adriatic Sea, the Apennine Peninsula and Sicily. (Picture.5.1)

[117] George F. Bass, *Beneath The Seven Seas*, Thames & Hudson Ltd, London, (2005), pp. 10-11

Picture 5.1 Map showing the ancient Greek conquest and the establishment of colonies on the Aegean islands, along the coast of the Adriatic Sea, the Apennine Peninsula and the islands of Sicily

The Roman Empire also based its development and imperial ambitions on imports of grain from the Black Sea and North Africa, trafficking wine, oil and other food products from all over the Mediterranean. All of these trade routes led across the waters of the Mediterranean Sea. Navigation and maritime trade reached its maximum development in this period. (Picture 5.2.) This same level of traffic in the Mediterranean Sea was reached again only a few hundred years later in the middle Ages, after several centuries of stagnation in these activities.[118]

[118] Parker, A.J., Artifact Distributions and Wreck Locations: The Archaeology of Roman Commerce, *Memoirs of the American Academy in Rome. Supplementary Volumes, Vol. 6*, The Maritime World of Ancient Rome (2008), pp. 177-196



Picture 5.2 The principal ports of the Roman Mediterranean and the currents of trade, according to the Aphrodisias fragments; (by Rouge 1966, 88-89, in Parker A. J., 2008, pp.178)

Concurrently, throughout this long period, the marine structures and the process of shipbuilding were evolving. Today, based on archaeological data collected from numerous underwater sites, we can understand how the process went in the past and how it was perfected. Regardless of our analytical vision and understanding of ships of the past, for the people who designed them, built them and sailed on them, the ships had completely different meaning. Simply, they were just a vehicles used for navigation to a distant land or a means of transportation of goods. What is quite certain is that the ships were, despite all the dangers of the sea, much more convenient, safer, faster way to travel, unlike continental roads.[119]

Mediterranean area contains many archaeological material remains of ancient civilizations that have historically influenced the development of modern communities. This great cultural and historical heritage is invaluable and is a testimony of human existence and activities of the past. At the same time, it is highly jeopardized and in great danger of destruction. There is a range of natural influences that threaten the underwater cultural heritage of the Mediterranean leading to its degradation and slow decay.

[119] Steffy, J. R., *Wooden ship building and the interpretation of shipwrecks,*(1994).pp.23-78

These factors are inevitable and their destructive impact cannot be stopped but by taking timely actions for the protection and conservation, their effect can be mitigated and the decay slowed down. On the other hand, a large and constant danger comes from different human activities. These effects, as opposed to natural, can cause degradation or complete destruction of underwater cultural heritage in a very short time period and represent the most important factor of degradation of underwater archaeological material in the post depositional stage.[120]

Whatever the reason that caused the destruction, once destroyed or damaged the authenticity of the underwater archaeological heritage cannot be restored to its original condition. In this way, valuable testimony of the past will be lost forever for the future generations.

The best way to ensure the survival of the cultural heritage of the Mediterranean is to develop innovative new methods for the purpose of its protection and conservation. For this reason, these sites must be carefully used and treated as a single, non-renewable resource. It is inevitable that they will be destroyed if they are left unprotected or exploited with no long-term plans. Unfortunately, there are very little long-term projects for the Mediterranean region with the main goal to protect the archaeological values and to raise public awareness.

Paradoxically, notwithstanding that international laws were passed on the protection and conservation, and public awareness raised of the value of UCH (Chapter2.1), the level of its destructions increasing. On one hand, economic growth and development cause total neglect of cultural values, and on the other, intense, and excessive exploitation of cultural heritage lead to irreversible degradation and destruction of the cultural values of many archaeological sites.[121]

[120] Beltrame, C., *Archeologia Marittima del Mediterraneo Navi, merci e porti dall'antichità ali'età moderna*, (2012), pp.33

[121] M. de la Torre and M. Mac Lean, *The Archaeological Heritage in the Mediterranean Region,* The Getty Conservation Institute Los Angeles,(1995),pp.5-14

5.2 GENERAL CHARACTERISTICS OF THE MEDITERRANEAN

5.2.1. PHYSICAL GEOGRAPHICAL FEAUTURES

Mediterranean means a land area that extends around the Mediterranean Sea, the Mediterranean Sea and all its islands. It spreads over three continents and includes the territory of Europe, Africa and Asia. Countries that gravitate to this area are called the Mediterranean countries. Some of these countries are located directly on the Mediterranean Sea; some come out only in part on its coast, while some have no physical contact with the sea. However, although they have no contact with the Mediterranean Sea, these countries historically and culturally belong to this region.

It is exactly because it was surrounded by many countries that the Mediterranean Sea got its name that comes from the Latin word "mediterraneus" which means, "in the middle of the earth" or "surrounded by land." Otherwise, throughout the history, Mediterranean Sea had several different names. For example, the Romans commonly called it Mare Nostrum (Latin. "Our sea") or Mare Interum (lat. "Inner sea").

The Mediterranean is located in moderate geographical region. It extends to an area located between 30° and 46° north latitude, 9° west and 38° east longitude. It stretches over a length of 3800km from the extreme east to the extreme west point and the largest width is approximately 1600km. It covers an area of approximately 2.5 million km2. The northernmost point of the Mediterranean is the base of the Alps in the Italian region of Veneto, the most western point is Cape Roca near Lisbon. To the east it goes to the Syrian Desert and the southern boundary is the coast of North Africa. With shallow undersea ridge, so-called Strait of Sicily, between the coast of Sicily and the coast of Tunisia, Mediterranean Sea is divided into two parts; Western and Eastern Mediterranean. (Picture 5.3)

Picture 5.3 Satellite images on which it is possible to see the geographical characteristics of the Mediterranean Sea (photo taken from www.googlemap.com)

The average depth of the Mediterranean Sea is about 1500m. The deepest point is around 5300m and is located in the Ionian Sea near the coast of Peloponnese in Greece.

The Mediterranean Sea is formed by several other seas' actually separated basins; Adriatic, Aegean, Tyrrhenian, Ionian Sea and the Algerian and Levantine basin. It is connected to the Atlantic Ocean through the 14km wide Strait of Gibraltar, where it performs a constant exchange of water masses. It is also connected to the Black Sea through the Bosporus, but it is implied that the Mediterranean and the Black Sea are two separate entities.

The total length of coastline that extends into the Mediterranean basin is 46,000km and it is very jagged because of its composition. The Mediterranean Sea has many islands, and some of the biggest are: Corsica, Sardinia, Sicily, the Balearic Islands, Crete, Cyprus and Rhodes, as well as many other, smaller islands, which are predominantly located in the Adriatic Sea. Each of these islands represents a specific entity; a small isolated continent with its own climate, flora, and fauna.[122]

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122 "The Mediterranean Sea", The Geonauts inquire into the oceans, OCA/CNES(2000),pag.1-5

5.2.2. CLIMATIC CHARACTERISTICS OF THE MEDITERRANEAN

The Mediterranean climate is characterized by its diversity, which depends largely on the specific geographic location. The northern part of the region (Europe) is characterized by warm, dry summers and moderately mild and relatively dry winter. South-eastern part of the region (the area of Africa and Asia) is characterized by dry or even desert climate.

The combination of strong winds and very dry climate and high temperature, condition the very large evaporation of water masses in the basin. This phenomenon is especially pronounced in the eastern part of the Mediterranean. It is assumed that the amount of water vapors is around 3 million tons that is almost three times more than the annual rainfall.

Average annual precipitation is relatively very low and ranges in value from 9 to 275mm depending on the area of the Mediterranean basin. Out of total rainfall, 65% occurs in the period of winter months. This large imbalance in the influx of water in the Mediterranean Sea is held with constant inflow of water from the Atlantic Ocean through the Strait of Gibraltar and the inculcation of water from rivers and catchments.[123]

123Lionello, P.,Abrantes, F.,Congedi, L.,Dulac, F.,Gacic, M., "The Climate of the Mediterranean Region"(2012), pag. xxxv-xc

5.2.3. SALINITY

Salinity is another very important feature, which is the consequence of a large evaporation of water masses in the Mediterranean. The value of salinity is not constant and it varies in proportion to the amount of vapour that primarily depends on the period of year. Water mass with an increased percentage of salinity is much denser and heavier compared to water with lower salinity. Due to its weight and density, salt water has a tendency to sink into the deeper layers of sea, which subsequently leads to a vertical stratification of seawater. (Picture.5.4)

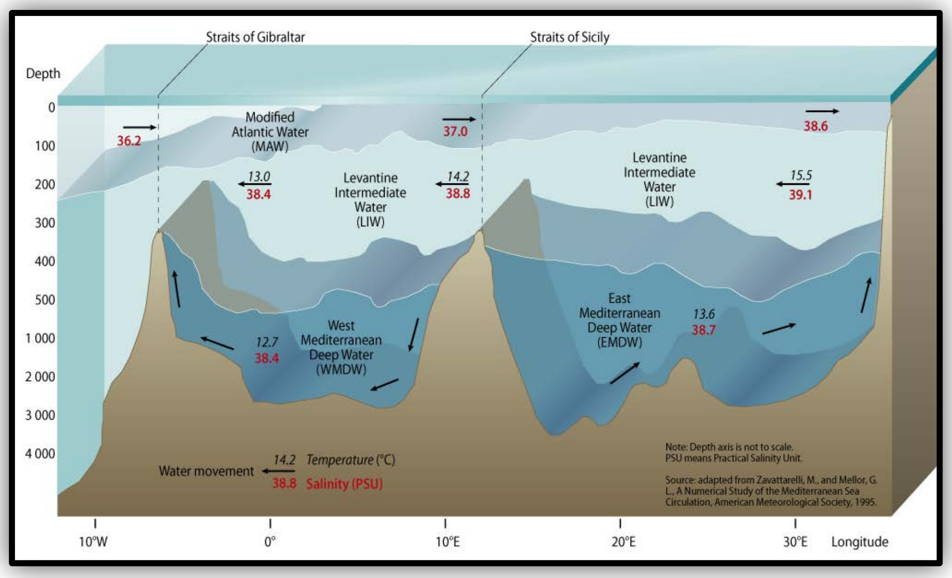
The Mediterranean Sea is composed of three main bodies of water that are arranged vertically one above the other in different thicknesses;

(1) The first is a surface layer having a thickness of 50-200m. The average salinity of this layer is 36.2% $_o$ near the Straits of Gibraltar, but it increases to 38.6% $_o$ in the Levantine Basin of the eastern Mediterranean Sea. (2) The middle layer is formed at a depth of 200-800m, and it has the average temperature of 13 to 15.5 ° C and salinity of 38.4%$_o$ in the west to 39.1%$_o$ in the east. (3) The Mediterranean deep layer is formed in the western Alboran basin and the Eastern Levantine basin. West Mediterranean deep basin has the average temperature of 12.7°C and salinity of 38.4%$_o$ while Eastern has the average temperature of 13.6°C and salinity of 38.7%$_o$. (Picture 5.4)[124]

Bearing in mind that these three layers are very different in their characteristics it is important to note that the directions of their movements are also different. The process of mixing water from these layers is a constant process and the intensity of mixing depends largely on the changes of seasons, which subsequently cause meteorological and atmospheric conditions.[125]

[124]Zavattarelli,M.,Mellor, G.L., *A Numerical Study of the Mediterranean Sea Circulation*, American Meteorological Society, 1995.

[125] Schroedera,K.;Garcìa-Lafuenteb,J.,Joseyc,S.A., Artaled,V., Nardellie,B., Carrillod,A.; Gačic,M., *Circulation of the Mediterranean Sea and its Variability*,(2012),pag.187-256



Picture 5.4 Mediterranean Sea water masse: Vertical Distribution (from Zavattarelli, M., and Mellor, G.L, 1995.)

The average value of salinity in the Mediterranean Sea varies between 36% -39‰, and this value is within these limits thanks to the mixing of Mediterranean water with water from the Atlantic Ocean.[126]Salinity and temperature are very important factors that may indirectly have very important role in the conservation of the underwater archaeological material. The particular value of salinity and temperature provide adequate conditions for the settlement of certain species of marine macro-and microorganisms that play a key role in the degradation of primarily wooden archaeological material. (See Chapter 4.1.2 Biological Threats)

[126]Zenetos, A.; Frangou, I.S.; Skretas, O.G. *Il Mare Mediterraneo*, Agenzia Europea per l'Ambiente, (2011)

5.2.4. SEA CURRENTS IN THE MEDITERRANEAN SEA

Specific geographic position of the Mediterranean Sea, its being cut off and its limited connection to the Atlantic Ocean cause a very slow circulation of water masses. For this reason, the existing sea currents do not have great intensity and tides are significantly reduced compared to the Atlantic Ocean.

Sea currents in the Mediterranean Sea are slow but continuous movement of water masses that affect the general circulation and mixing of seawater. Because of the very specific geomorphology of coastline and seabed of the Mediterranean Sea, the number of local sea currents is very large. The basic characteristics of these currents are direction, speed, and permanence.

The direction of these currents is generally constant during the year. Changes or the creation of new local water currents depend mainly on the season. The biggest influence on them is the flow of water from the Atlantic Ocean through the Straits of Gibraltar,[127] the temperature and density of seawater, wind, and geological configuration of coastline and bottom.[128]

The average speed of the sea currents in the Mediterranean Sea is between 1-2.5 m/s. The depth to which it is possible to feel the impact of the sea currents is relatively small and rarely exceeds 100 to 150 m in contrast to the Gulf Stream in the Atlantic Ocean, reaching the depth of 650 m.

The difference in the density of water and its specific weight also has the influence on the formation of ocean currents.

The cold water with a high percentage of salt is considerably heavier than the warm surface water with a low percentage of salt. The heavy water has a tendency to get down to lower (deeper) layers of the sea. (Picture.5.5)

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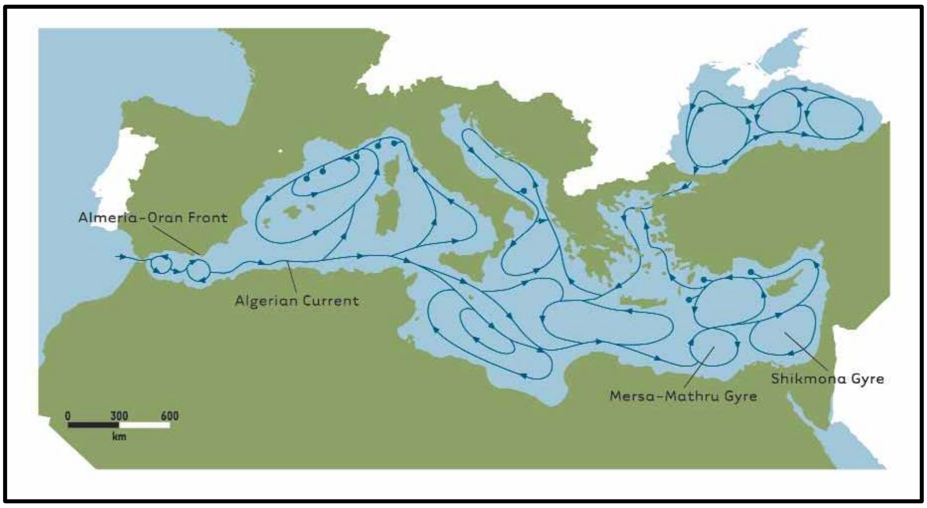
[127] Millot, C., Circulation in the Western Mediterranean Sea, *Journal of Marine Systems 20,*(1999), pg. 423–442

[128] C. Millott and I. Taupier-Letage, Circulation in the Mediterranean Sea, *Hdb Env Chem Vol. 5, Part K*, (2005) 29-66.

The truth of this assertion is best determined on the Bosporus Strait that connects the Black Sea with the Mediterranean. Less saline and lighter water from the Black Sea has a surface flow and flows into the Mediterranean Sea. This causes quite a strong current and a reduction in salinity in this part of the Mediterranean Sea. At the same time, at the bottom of the strait, the reverse process takes place. The waters of the Mediterranean Sea, known for its high salinity, flow into the Black Sea. (Millot, 1999), (Millot & Taupier-Letage, 2005), (Schroedera, et al., 2012)



Picture 5.5Photo shows the circulation of dominant currents in the Mediterranean Sea (Source: Tomczak & Godfrey, 2003)

The influence of the Earth's rotation also has a great impact on the formation of sea currents. The molecules of water are affected by its rotation, which tends to draw right on the north and to the left in the southern hemisphere. In the enclosed seas such as the Mediterranean, sea currents create a circular system independent of the ocean. These currents are much higher under the influence of Earth's rotation as opposed to the current in the ocean. For this reason, in the Mediterranean Sea and its coastal areas a system of sea currents was developed with the direction of the circulation predominantly in the anticlockwise direction.

The flow of the water in the Adriatic Sea is connected with the currents of the Mediterranean Sea. From the Ionian Sea, a current flows toward the north through the Otranto Strait and continues its course along the eastern coast of the Adriatic Sea to the northwest. Near the island of Vis and Korčula,it begins to separate into smaller streams, which are deflected to the west coast. In front of the southern coast of Istria, main current splits into two streams. A smaller stream goes to the city of Rijeka and the other turns to the west. This flow off the western coast of Istria and Trieste bay, caused by a strong cyclone movement of air masses, re-turns to the west coast of the Adriatic Sea and, connecting with other backwaters, extends further towards Otranto. This sea current of the North Adriatic, further enhances the exceptionally strong north-eastern wind Bura that is the characteristic of this region. The main feature of this sea current is a transport of significant quantities of river water, which is colder and less salty, resulting in moving more quickly. Rivers that flow into the northern Adriatic, belonging to the Alpine river basin and the largest rivers are certainly Piave, Livenza, Isonzo, Tagliamento, Brenta, Adige, and Po.

The rivers in their upper course are torrential rivers that carry a large amount of erosive material that forms the main source of sedimentary material. This material is deposited on the confluence of the river to the sea, creating a raised sandy and stony coast, which is very susceptible to the effects of sea currents. This phenomenon is very pronounced in the spring months during the year, after the melting of snow in the Alps, when an extremely large amount of sedimentary material is deposited.

High hydrodynamic energy of north Adriatic Sea currents causes erosion of river sediment, which causes its displacement from the original position, transport, and disposal at some other remote location. This relocation of river material causes constant modification of the coastline as well as the profile of the seabed due to the accumulation and erosion of sedimentary deposits. The result of this process could affect the creation of lagoons. These geological formations are highly specific for the northern Adriatic.

The process of their creation is very complex and represents the interaction of various natural factors and the most typical example of the creation of this type of geological phenomena is the Venice lagoon.[129]

It is important to note that the sea current of the northern Adriatic Sea and its high hydrodynamic energy that transports large amounts of erosive material has a very important role in the conservation of archaeological remains and shipwrecks in shallow coastal areas and on beaches.[130] This phenomenon will be described in more details in the following paragraphs.

Sea current that runs along the eastern coast of the Adriatic Sea is warmer, saltier and moves more slowly. The speed of currents along the eastern Adriatic coast is much slower compared to the western current, along the Italian coast. Slower movement of sea currents along the eastern coast of the Adriatic Sea is explained by the significant coastal indentation, which slows the movement of water masses.

The configuration of the bottom and winter freezing of water masses in the northern Adriatic determine the depth of sea currents. During winter, the reduced inflow of water from rivers and insufficient rainfall, low temperatures cause the lowering of the sea level in the northern Adriatic. Heavier cold water flows at the bottom of the range of the Adriatic and its average temperature for the year is about 11°C.

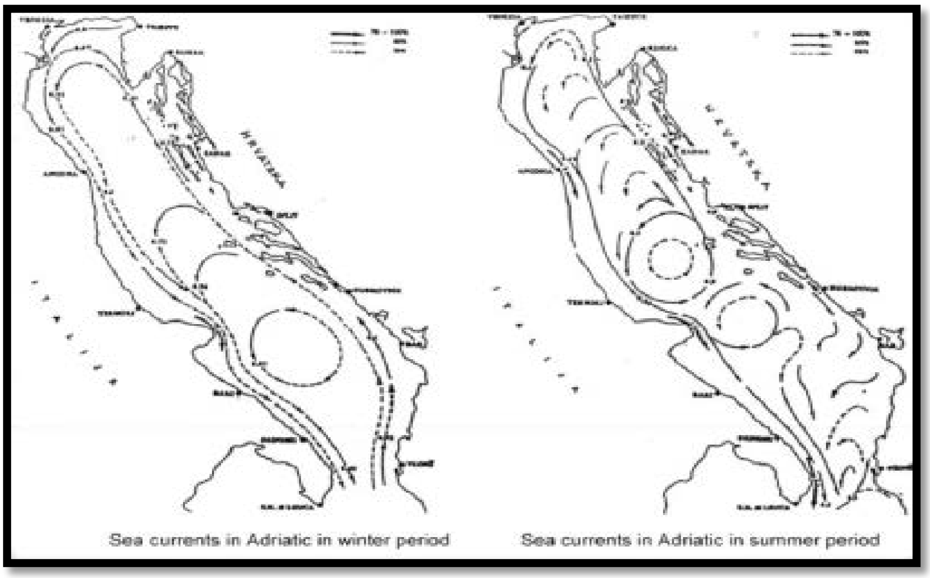
To compensate for such a flow, which has the direction towards the southeast, an increased flow is created on the surface from the Ionian into the Adriatic Sea, with a tendency to compensate for the difference in height of the northern Adriatic. Therefore, during the winter the currents at the entrance to the passage of Otranto are strong, and with slightly lower output.

In the spring, especially in summer the situation is completely reverse. Due to snowmelt and increased inflow of the water, level in the northern Adriatic

[129] Zanetti, M.,Laguna di Venezia :Passato,Presente e Futuro- Salvaguardia e Prospetive, (2011), pag. 1-8

[130] Carlo Beltrame,Tutela e conservazione dei relitti in ambiente di spiaggia, in F. Maniscalco (a cura di), *Tutela, conservazione e valorizzazione del patrimonio culturale subacqueo*,(2004), vol. 4, Napoli, pp. 141-150

Sea is rising; swelling is carried down the side of the eastern part of Apennines. For this reason, in summer months Adriatic output current is stronger than at the entrance to the Strait of Otranto.



Picture 5.6 Photo shows the seasonal circulation of sea currents in the Adriatic Sea. (Left) sea currents during the winter months; (right) circulation of sea currents and water masses in the summer.

5.3. CONSERVATION OF UNDERWATER ARCHAEOLOGICAL CULTURAL HERITAGE IN THE MEDITERRANEAN

The Mediterranean Sea contains vast underwater archaeological and historic cultural heritage. It is very difficult to determine the exact number of shipwrecks in the region. First, because this great cultural and historical legacy lies in the vast space, but also because it is located in the territorial waters of 21 countries and international waters of the Mediterranean region. According to surveys and assessments conducted in '90 of the last century (Parker, 1992), it is assumed that there are about 1,200 shipwrecks in the Mediterranean that are older than 1500.[131]

The Parker's assessment must be accepted with extreme caution, as the list of shipwrecks is not definitive. There are assumptions that there are many more shipwrecks that lie at the bottom of the Mediterranean Sea. The reason for this thinking is that currently there is no unified database for the Mediterranean region, from which it would be possible to obtain information about all the sunken ships and objects in the Mediterranean Sea. One reason for the lack of complete information on the number of archaeological sites in the Mediterranean area is that some states have not conducted a systematic survey of the underwater world.

It is enough to bear in mind the fact that according to the research of the French department of underwater research DRASSM (Departement des recherches archeologiques subaquatiques et sous-marines) only on the bottom of the French territorial waters there are3000 registered objects and the archaeological remains of which even 2000 are the remains of sunken Ships.

[131]Parker, A.J., 1992: Ancient Shipwrecks of the Mediterranean and the Roman Provinces, *BAR International Series 580*, Oxford

5.3.1 BIOLOGICAL BACKGROUND AND ANCIENT REFERENCES

Mediterranean Sea, as we have seen in the previous paragraph (chapter 5.1), because of its physical, climatic and temperature characteristics belongs to the category of warm sea, with hot, dry Mediterranean climate. Such conditions are extremely favorable for the development of macro-organisms T.navalis, Xylophaga dorsalis (See chapter3.1.2.1), as well as micro-organisms, mainly bacteria and fungi, which are the most significant parasites of wood and biological factors that lead to the degradation of wood in underwater environment.[132] (Bjordal C. N., 2008), (Kim & Singh, 2000)

Invasive organisms that attack and destroy wood are nothing new in the region of the Mediterranean Sea. Problem with these organisms has existed since ancient times. With the help of valuable ancient records, the historians of maritime navigation and underwater archaeologists have come to important information related to maritime navigation and ancient shipbuilding.[133] In those ancient scripts, there are also testimonies of the existence and wide dispersion of T.navalis which has always been a big problem for ancient mariners and shipbuilders.

For example, Vitruvius in his texts mentions a big problem that T.navalis causes and what devastating consequences it can have on wood. He advised that all boat docks must be built facing the north, because south side provides more sunlight and heat which is necessary for colonization and reproduction of these parasites.[134]

[132]Pournou, A., Bogomolova, E.,;Fungal colonization on excavated prehistoric wood: Implications for in-situ display, *International Biodeterioration & Biodegradation 63* (2009),pp. 371–378

[133]Morrison, J. S. & Coates, J. F., *The Athenian Trireme.* Cambridge University Press, Cambridge and New York, 1986, pp. 230-233.

[134]Vitruvius, (De arch., 5.12.7)

In addition, Polybius describes T.navalis in his work as “Inbred pests, which, as iron rust, destroys wood from the inside ... Wood looks undamaged on the outside but it is eaten from the inside."[135]

A large number of ancient authors of classical literature, whose literary works have been performed in the ancient theatre, used the aggressive nature and specific behavior of T.navalis to achieve a poetic allusion or metaphor.... In this way, a large part of the audience and the general population of the ancient world, and not only sailors and shipbuilders, were very familiar with T.navalis and its destructive effect on wood. That knowledge among the people of the Mediterranean has survived for hundreds and thousands of years later.

In addition to the ancient written sources, a lot of accurate information about destructive effects of T.navalis can be obtained from the archaeological evidence from the Mediterranean Sea. In this area, a few very important shipwrecks from ancient period were found. Archaeological work on these shipwrecks gave very important information about maritime trade routes in the Mediterranean, life on board as well as in the whole region. Above all, archaeologists have found the information about the shipbuilding technology of the period. One of these ships is Kyrenia, a merchant ship from 4.BC. After careful analysis, Richard Steffy accurately described details of the ship's structure. Especially important is the discovery of some reparation of planks on the hull that were heavily damaged due to the activities of T.navalis, which later was the cause of the ship sinking.[136]

In the modern world in which we live today, people generally make ships from metal or synthetic composites that considerably simplify the construction, reduce costs, and at the same time provide superior robustness and durability compared to wood.

[135] Polibius, (Histories, 6.10.3)

[136] Steffy, J. R., The Kyrenia Ship: An Interim Report on its Hull Construction. *American Journal of Archaeology 89,* (1985)pag.95-97

However, many fans and admirers of traditional shipbuilding using wood as building material and those lucky owners of wooden boats, now have at their disposal countless chemicals and coatings that protect the ship's construction from wood parasites, shells and algae.

Unlike modern times, in ancient times, ships were made entirely of wood. In addition, there were not effective protective chemicals like today. Bearing in mind the constant presence and threat of parasites, wooden ships of the time were in constant danger of serious damage that very often resulted in the sinking of the ship during a long trip.

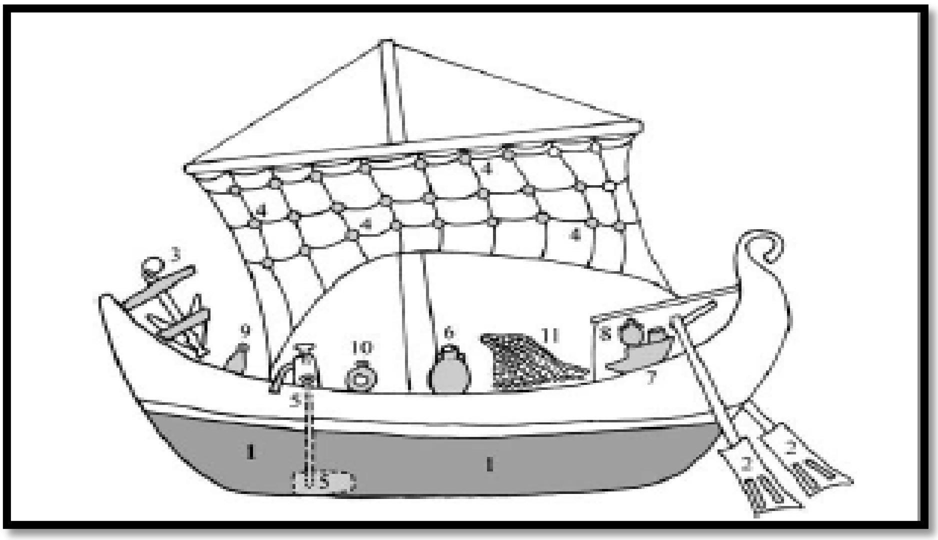
The strategy that was used in the ancient world in order to protect the hull from the destructive effects of the wood parasites was (1) fixing the lining of the hull, mainly merchant vessels (Hull Sheathing); (2) extraction of the ships out of the water at the beach or the use of cover (ship sheds) for drying and repair.[137]

Underwater research in the Mediterranean Sea, especially along the Israeli coast, led to the discovery of a large number of objects of lead originating mainly from the Roman ships. Detailed research and analysis of these findings indicated that the lead was widely used for the production of certain parts of the ship as well as ship construction.[138] (Picture..5.7)

A large number of these artefacts constitute parts of lead coverings for the hull.(Rosen & Galili, 2007) Lead is a metal that is highly available, easy to work with, and resistant to corrosion, and therefore had a great and versatile use in antiquity.

[137]Steinmayer Jr,Alwin G., Jean Macintosh Turfa,Effects of shipworm on the performance of ancient Mediterranean warships, *The International Journal of Nautical Archaeology,* (1996) 25.2; pp.104- 121

[138]Rosen B., Galili, E., Lead Use on Roman Ships and its Environmental Effects, *The International Journal of Nautical Archaeology*, 36.2, (2007), pp. 300–307



Picture 5.7 Schematic distribution of lead artefacts on a Roman ship. (Photo E. Galili, pag.301)

Due to all these characteristics, the material was suitable for the sheeting of the ship hull. Protective coating was nailed to the hull immediately after completion of ship construction. The hull was coated from the keel up to the waterline. To repair the damaged ship's lead shield, the crew used lead strips and patches, which were found at the archaeological sites.[139](Picture.5.8)

Lead protection of the ship hull was a very reliable method for protection, and has been practiced for a long time, mainly for the protection of the Roman military ships. It is very resistant to corrosion and because of its weight; it gives very good ballast to the ship, without consuming valuable space on board intended for shipload. Finally, it provides excellent protection against the parasites and wood boring organisms, particularly from the T.navalis

[139] Kahanov,Y.,Some Aspects of Lead Sheathing in Ancient Ship Construction, in H. Tazalas (ed.),Tropis V, *Hellenic Institute for the Preservation of Nautical Tradition*, Nauplia, Athens,(1999).

Picture 5.8 Hull parts: A, spare rolls of lead sheathing, B, lead patches, Lead material was often been found on underwater archaeological sites in the waters of Israel. Used for rapid intervention in repairing of the ship hull. (Photo, Rosen & Galili, 2007, pp.302)

The negative side of using lead is its toxicity, [140] to which the sailors were constantly exposed.[141]In addition, after the shipwreck, lead that was deposited on the sea floor also may cause pollution of the local environment. For this reason, the toxicity of lead has been providing additional protection from parasites. (Rosen & Galili, 2007)

Another very effective way of combating marine woodborers in the ancient world was periodic or seasonal extraction of vessels from the water to dry. The boats are pulled mainly on the beach or on a special covered shelter (ship sheds), intended mainly for military ships.[142] (Picture.5.9)

Ports from classical period had a covered shelter, a kind of hangar, where over the long sloped terminal (Slipways). Ships were pulled out from water

[140]Nriagu, J. O., *Lead and Lead Poisoning in Antiquity*. New York,1983

[141]Scarborough, J., 1984, The Myth of Lead Poisoning Among the Romans: An Essay Review, *Journal of the History of Medicine 39*, pp.469–75.

[142] Coates.J.F.& Shaw,J.T.,Hauling a trireme up a shipway and up a beach. In T. Sbaw (Ed.),The Trireme Project:(1993),87-90.Oxbow,Oxford.

by huge winch for drying. At the same time, it was also a place where they could make any necessary repairs to the ship's structure.[143]

Picture 5.9 (foto1) The remains of the ancient Greek military port (Apollonia, Libya); (foto2) underwater image of Slipways through which, with the help of a special mechanism, the ships are pulled out from water on drying; (Photo by Vladimir Danilovic, Carlo Beltrame from photo documentation project Apollonia, Archeotema-Venezia 2009)

Pulling ships out of the water and drying the ship's construction is a very good method to prolong the life of the ship because seasonal drying involves a period of several months in a completely dry and protected environment. This period is long enough to destroy the structure of the cavity created by T.navalis and simultaneously to ensure certain death of the parasite. (Steinmayer & Turfa , 1996)

Antique military navy gave much attention to the treatment of ships because the ships so treated had a much longer lifespan. It is estimated that a warship could be in use for about 20 years.

[143] Beltrame,C., *Archeologia Marittima del Mediterraneo Navi, merci e porti dall'antichità ali'età moderna,* (2012), pp.251-258

Unlike the ships that were constantly submerged in water, which had extremely high level of damage and which became practically useless after a few years.[144]

[144]Casson,L.,Ships and Seamanship in the Ancient World. Princeton University Press, Princeton.(Additional notes in 1986 paperbound edition)(1971/86), pp.89-90

5.4. CASE STUDIES IN MEDITERRANEAN SEA

The reason for the wide spread of T.navalis the Mediterranean Sea, are appropriate natural and environmental conditions highly favorable for the settlement of T.navalis. These include the salinity of seawater, which must have a minimum value of 12% $_o$. Then, the optimal water temperature is in the range between 15-25C°. Extreme temperatures below 0C ° and above 35°C, are not favorable because they can cause death of T.navalis. (See chapter 4.1.2.1.1. T.Navalis, Linnaeus, 1758 (Mollusca, Bivalvia, Teredinidae) and (Chapter 5.2 General characteristics of the Mediterranean)

Bearing in mind that in the Mediterranean there is a stable and warm Mediterranean climate, without major temperature fluctuations throughout the year, the activity of T.navalis is extended for the period of the entire year, in contrast to other areas with different climatic conditions with large temperature changes.[145]

Based on all these facts, it can be logically concluded that in the Mediterranean Sea the danger of T.navalis invasion and its destructive effect on ancient ships and timber structure is constant.

However, it must be emphasized that T.navalis is not the only one, although certainly the most notorious, invasive organism that attacks the wood and leads to its destruction. Many, very dangerous wood boring organisms inhabit the waters of the Mediterranean Sea. These organisms have the absolutely most important role in the degradation of wood, and therefore in the conservation of archaeological wood material and its long-term survival. All this clearly leads to the conclusion that biological factors with diverse and highly complex physical processes (Quinn, 2006), which, depending on the region of the Mediterranean can be very severe they can dramatically affect the dynamics of degradation of the structure of the ship.

[145] Richards, B. R., Marine Borers. In R. W. Meyer & R. M. Kellogg (Eds), Structural Use ofWood in *Adverse Environments: Society of Wood Science and Technology*. New York. (1982), pp.265-273

In some extreme cases, these processes can lead to the complete destruction of the wooden structure.[146]

Some experimental projects carried out in the Mediterranean Sea in recent years support the claim that biological factors play a key role in the degradation of wood. One of the most important is the PLoS-One project, which was performed by a group of scientists from the University of Delaware in the United States.[147]

The main objective of this project was to study the biogeochemical effects that are created on the sea floor around the wood that comes from the surface as well as the creation of ecosystems of macro and microorganisms during the entire process. In addition, one of the main objectives was to identify the organisms that inhabit the wood and to expand the knowledge of the parasites of wood, primarily macro-organisms wood-boring bivalves and microorganisms (bacteria and fungi) that inhabit the waters of the Mediterranean Sea and leads to degradation of wood.

The project envisaged placement of wooden samples at several different locations in the eastern Mediterranean at a depth of 1650m and on different substrates in order to examine whether the characteristics of the seabed have an impact on the colonization of wood.

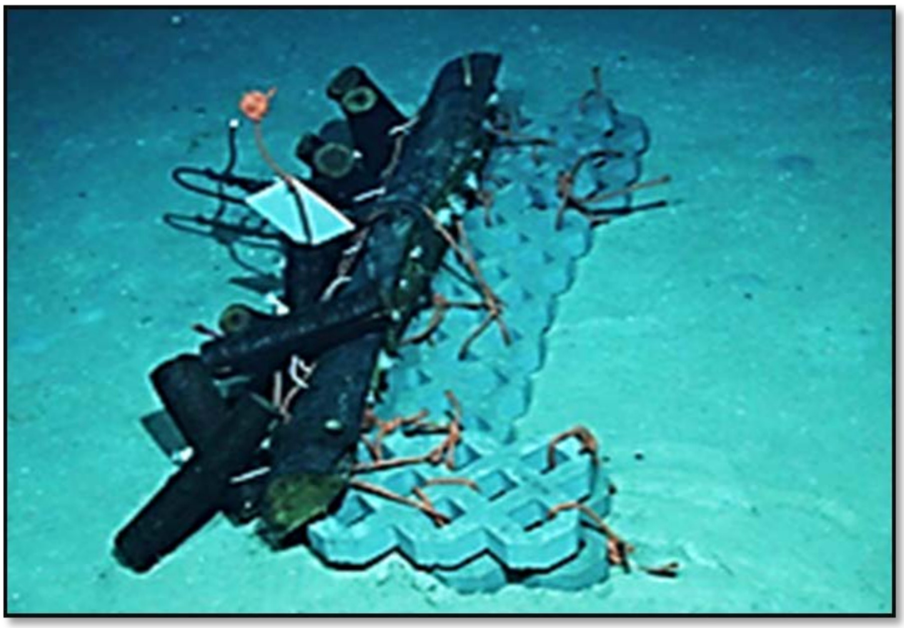
The project envisaged the monitoring in certain intervals in order to study the dynamics of colonization of the wood and the development of biogeochemical factors. (Picture 5.10)

For this experiment, four wooden logs were used, 2 m long and with diameter of 30cm and few smaller wooden logs of 30-50cm length and diameter of 10-15cm, which were joined by heavy concrete blocks that allowed the samples to remain, fixed on the sea bottom.

[146] P. A. Gianfrotta, P. Pomey, *Archeologia subacquea: storia, tecniche, scoperte e relitti,* Milano, Arnoldo Mondadori Editore, (1981),

[147]Bienhold,C.,Ristova, P.,Wenzhöfer,F.,Dittmar,T.,Boetius,A.,How Deep-Sea Wood Falls Sustain Chemosynthetic Life, PLoS ONE 8(1), University of Delaware, United States of AmericaJanuary 02, 2013

The initial idea was that the larger wooden logs provide hiding place for macro fauna and that they must remain on the bottom during the entire duration of the project. Smaller parts of the wood are planned for periodic extraction using remotely controlled vehicle (ROV) to establish the rate and extent of colonization and possible damage caused by aquatic organisms. (Picture 5.10)



Picture 5.10 Wood samples on the seabed deployed in the Eastern Mediterranean deep sea (2006) (photo PloS ONE project pag.2)

After a year spent at the bottom of the sea, in-situ observation of wooden logs, indicated a high level of degradation due to the colonization of several different types of wood boring organisms (Picture 5.11)

A large number of characteristic cavities and white shells indicate the presence of large mollusks Xylophaga dorsalis. Severe degradation of the wood mass was caused precisely because of the colonization and the destructive effects of this organism, which were also the most numerous. The number of individuals in all four samples was extremely high and ranged from 100-500 individuals per 1m2 and the colonization affected all the surfaces of the sample.

The size of individuals that inhabited the experimental wooden log was between 1-10 mm, which depends largely on the age of the organism.

Picture 5.11 Macro fauna colonizing the woodensample after one year at the sea floor (photo PLoS ONE project pag.5)

One of the primary goals of this project was the determination of the presence of bacteria on the surface of the sample and the degree of degradation that can be caused. Subsequent analysis in the laboratory showed the presence of a large number of bacteria of the genus Alphaproteobacteria, Flavobacteria, Actinobacteria, Clostridia, and Bacteroidetes. These bacteria pose a great danger to wood, because due to their activities they degrade the cellulose of cell structure of wood. In this way, these bacteria damage the structure of wood that loses its strength and becomes very fragile and subject to physical impacts from the environment.

In addition, a very important characteristic of these bacteria is that they can survive in anoxic environments, i.e., areas with extremely low concentration of oxygen. This practically means that these bacteria pose a threat to wooden material at greater depths of sea, as well as under thick layers of marine sediments in the lower depths of the sea where the presence of air is also reduced.

Findings and conclusions reached by scientists after the completion of the experiments further supported earlier hypotheses, and previous researches that in the Mediterranean Sea the key organisms that lead to rapid biological degradation of wood materials are mollusks T.navalis and Xylophaga dorsalis as well as certain types of bacteria that cause a slow but long-term degradation.

5.5. COMPARATIVE ANALYSIS WITH THE REGIONS OF THE BALTIC SEA

The processes of degradation of archaeological wooden materials that is caused by biological along with physical factors are normal in the seas and oceans around the world. Such situation is in the Mediterranean, the Pacific, and the Atlantic Ocean and in the North Sea.

Probably the only place where these factors are not present is the Baltic Sea. Due to its specific characteristics, the Baltic Sea has excellent conditions for the conservation of the underwater archaeological material. For this reason, at the bottom of the Baltic Sea lie many well-preserved shipwrecks of great cultural and historical value. Such good conditions are rare, and it is hard to find a place like that with such a large number of intact vessels. The assumption is that there are over 100,000 ship remains at the bottom of the Baltic Sea. Out of that number, 6,000 shipwrecks are protected because of their archaeological and historical importance. Nine countries share this very important cultural historical and archaeological heritage. This number is not final and increases every year. (Bjordal & Gregory, 2011)

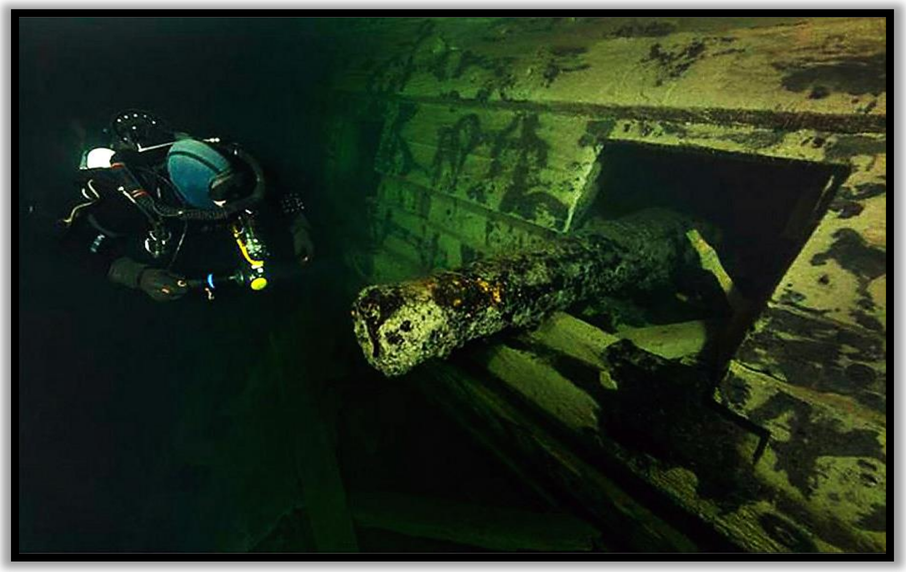
The Baltic Sea is very specific because of its characteristics and is one of the younger geological formations. Fossil remains, and paleontological evidence confirms that the Baltic Sea was created in the period between 14.5 -12.9 Kya (thousand years ago) after the defrosting of the Scandinavian ice sheet. On that occasion, the "Baltic Ice Lake "was first created. Later, that glacier lake merged with waters of the Atlantic Ocean approximately 11.5 Kya due to geological changes primarily because of the rising of global sea level caused by global warming.[148]

Simultaneously with the withdrawal of the ice sheet and creation of a new landscape suitable for habitation, people began to settle on the shores of the Baltic.

[148] Burroughs, J.W., *Climate Change in Prehistory -The End of the Reign of Chaos*, Cambridge University Press,(2005), pp. 60-61

One of the main activities of these prehistoric people was the construction of boats and navigation. This tradition has remained for millennia until the present day. This is the main reason why there are so many ship remains on the seabed in this area.

The most important characteristic of the Baltic Sea is very good conservative environment in which several centuries old shipwrecks lie on the seabed intact and undamaged, while closer to the coast, there exist exceptionally well preserved remains of port installations.[149] (Picture 5.12)



Picture 5.12 Svardet Swedish warship sunk in the naval battle of Oland, 1676 Ship's hull is exceptionally well preserved at the bottom of the Baltic Sea (photo M. Manders, 2011)

The explanation for this phenomenon are the physicochemical characteristics of the Baltic Seawater, which is brackish with a very low concentration of salt, which is not suitable for colonization of wood boring organisms that normally have a very degrading effect.[150] (Gregory & Manders, 2011) (Gregory, Jensen, Stratkvern, Lenaerts, & Pieters, 2011)

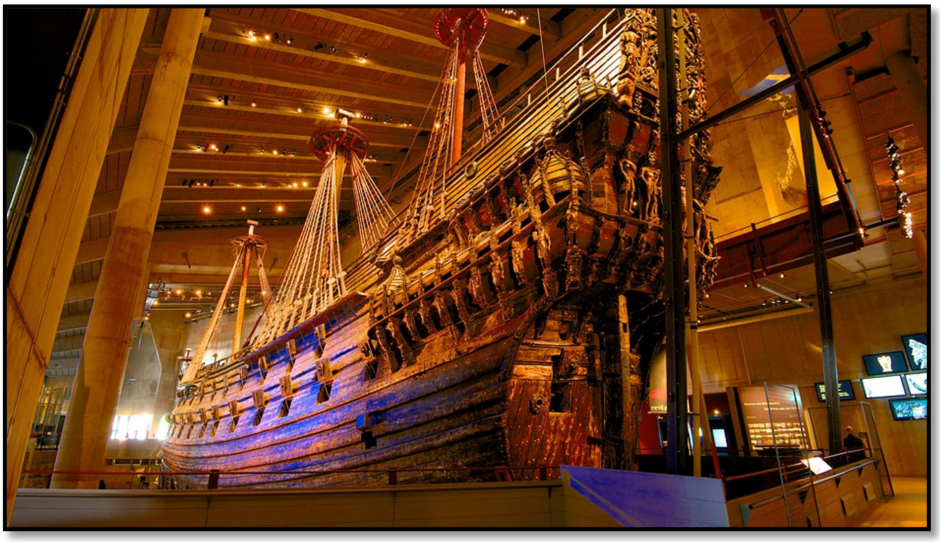
[149]David Gregory & Martijn Manders, The Baltic Sea: a unique resource of underwater cultural heritage, in Bjordal,C.G.,Gregory,D.,*Decay and protection of archaeological wooden shipwrecks, WreckProtect Project,* (2011), pp.8-10.

[150]Gregory, D., Assessing the burial environment and deterioration of organic archaeological materials, *SASMAP Project* ,pp.16-24

Another reason that contributes to the good conservation of the archaeological remains is geographical, geological, and climatic characteristics of the region. The climate in this region can vary between mild Atlantic climate and harsh continental. These climate variations condition very low temperatures during winter and hot dry weather during summer. In addition, Baltic Sea is a closed sea and therefore there are no strong currents that could enhance the physical processes that threaten the archaeological remnants. (Ward, 1999) (Quinn, 2006)

In the Baltic Sea, there are several outstanding examples of good conservation of underwater archaeological remains.

Certainly, the most famous example is the Swedish Royal warship Vasa from the 17th century. This ship, after centuries of lying on the seabed of the Stockholm harbor, was taken from the seabed, conserved, and exposed in the museum, which is dedicated to this ship.[151](Picture 5.13)



Picture 5.13 Swedish Royal warship Vasa, which sank in 1628 shortly after launching. One of the most famous ships from the Baltic Sea exceptionally preserved and exhibited in a museum that is dedicated to this ship. (Photo taken from Vasa Museum, Stockholm; http:// www.expedia.com/Vasa-Museum-Stockholm.)

[151]Cederlund, C. O., *Vasa: The Archaeology of a Swedish Royal Ship of 1628*, (2006).

Another very interesting and very important example is the submerged wooden Dutch merchant ship with two masts Vrouw Maria (Lady Mary).[152]This shipwreck is located in the Finnish territorial waters, in the southern part (Archipelago Sea) on the maximum depth of 41m. Maximum length of the wreck is 26.34m, the maximum width of 7.10m and the height 6m. The wreck itself and the bulk material from the ship and cargo are spread on an area of 1500 m2.The ship is located on the bottom of the sea, set upright on its keel. Hull is exceptionally well preserved and partially buried in the sand.

The upper parts of ship structures are completely uncovered and exposed to environmental influences, because there is not a lot of sedimentation on the site.[153]

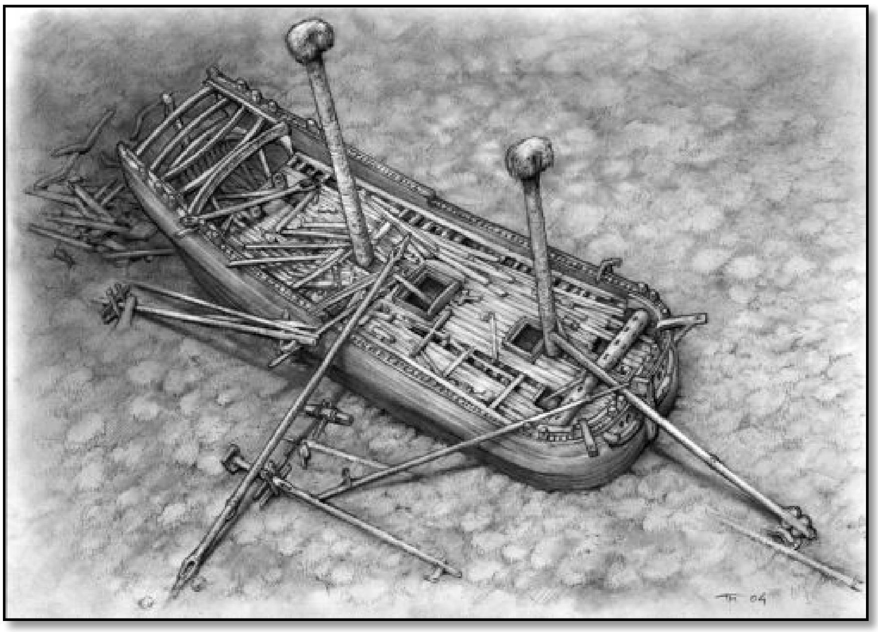
At first glance, the ship looks quite complete and not damaged, missing a few parts like a couple of boards, helm, and captain's cabin. (Picture 5.14) The process of shipwreck formation (sinking/wrecking process) can explain these defects.

Ship masts that are still present on the wreck confirm exceptional conservation of shipwrecks. The main mast rises to a height of 19m, while the front mast is 17m high.[154]

[152] Leino, M. Introduction of the Wreck of Vrouw Maria, *MoSS project*,(2000),pp..4

[153] Wessman, S.,The documentation and reconstruction of the wreck of Vrouw Maria. *MoSS Newsletter.1*, (2003) pp.14-17.

[154] Wessman,S., Vrouw Maria, in Bjordal,C.G.,Gregory,D.,*Decay and protection of archaeological wooden shipwrecks, WreckProtect,* (2011), pp.10-12



Picture 5.14 Perspective drawing of Vrouw Maria (Tiina Miettinen, National Boardaf Antiquities, Finland) (MoSS Project 2011 pag.11)

Underwater site of Vrouw Maria is under special protection since 2001. Since then, over the next three years it was a part of the European programme (Monitoring, Safeguarding and Visualizing North-European Shipwreck Sites (MoSS): Common European Underwater Cultural Heritage - Challenges for Cultural Resource Management).

This three-year project is aimed at establishing the presence of the parasite wood and their influence on the wooden structure of Shipwreck Vrouw Maria by placing wood samples and their monitoring for a period of three years. At the end of the project, after detailed analysis, research results were negative and the presence of wood boring organisms was not established.

However, on the site the presence of microorganisms is established that cause slow degradation of wood, especially soft rot fungi and bacteria.[155]

[155] Leino, M., Ruuskanen, A., Flinkman, J., Kaaslnen, J., Klemela, U., Hietala, R., & Nappu, N., The natural environment of the shipwreck VrouwMaria (1771) in the Northern Baltic Sea: an assessment of her state of preservation. *International Journal of Nautical Archaeology 40.1,* (2011). pp.133-150.

In addition to these above-mentioned shipwrecks, many other shipwrecks are very well conserved in the natural conditions of the Baltic Sea. Certainly worth mentioning is The Royal Swedish ship Kronan which was sunk in the naval battle of Oland, June 1, 1676. [156] According to contemporary records, she was one of the largest sailing vessels in Europe at the time. (Picture 5.15)

During the archaeological survey of the shipwreck was found several favorable factors that have caused the exceptional preservation of the ship. First, the rapid sinking after an explosion and deposition on the seabed. The seabed is a thin layer of sand over a thick layer of glacial moraine and clay that protects any organic or inorganic object embedded in it. Because of the low salt concentration, no presence of marine wood boring organisms such as Teredo Navalis have been observed on the site.[157]

Picture 5.15 The Royal Swedish ship Kronan was sunk in the naval battle of Oland, on 1 June, 1676. (photo Einarsson, L., WreckProtect 2011.)

All these examples of shipwrecks from the Baltic Sea undoubtedly leads to the conclusion that there are substantial differences between the

[156] Einarsson ,L., The Royal Swedish ship Kronan, in *Decay and Protection of archaeological wooden shipwrecks, WreckProtect*, edited by Charlotte Gjelstrup Bjordal, David Gregory Information Press, Oxford ,(2011), pp. 19-23

[157] Einarsson, L., Kronan - underwater archaeological investigations of a 17th century man-of-war. The nature, aims, and development of a maritime cultural project. *International Journal of Nautical Archaeology vol.19.4,* (1990), pp 279-297.

Mediterranean and the Baltic Sea. These differences are primarily related to the biological and physical characteristics that indirectly determine the potential for the conservation of archaeological material.

However, there is another very big difference when you compare the area of the Mediterranean and the Baltic and it refers to the awareness and attitude of the population towards the UCH. The Baltic Sea due to its conservative properties keeps at its bottom a few thousand perfectly preserved ship remains and for this reason it is considered as a giant underwater museum. Bearing in mind that the sea is surrounded by nine countries, this huge cultural, historical, and archaeological heritage belongs to the European people and not just to one nation or exclusively to the countries in the region that surround the Baltic Sea. (Bjordal & Gregory, 2011)

It is of great importance to raise awareness about archaeological values of the population of this region and there were numerous joint regional projects that were carried out in recent decades. Some of the most important projects are; Wreck Protect, SAS map, MoSS Project, Rutilus Project, the Co-operation on the Baltic Sea Cultural Heritage Project and many others.

The main goal and purpose of these projects was to record by means of a comprehensive scientific study the most significant factors leading to the biodegradation of wood as well as to determine the extent of damage and vulnerability; to raise awareness about common history and values of the UCH through legislation and scientific publications and workshops with practical demonstrations of in-situ conservation and monitoring; to develop strategies for sustainable development and conservation of UCH in the Baltic region.

Bearing in mind that the Mediterranean area lacks a large and long-term project of this type, it would be necessary to invest more effort and follow the excellent example of the Baltic.

5.6. THE MAIN CHARACTERISTICS AND PROBLEMS RELATED TO CONSERVATION IN THE MEDITERRANEAN SEA

Bearing in mind the differences between the Baltic and the Mediterranean Sea, we can conclude that the Mediterranean Sea is less favorable environment for the conservation of the underwater archaeological material. In this region, the process of natural conservation is very complicated and depends on many factors. Primarily on biological ones whose role in the Mediterranean Sea is crucial for conservation.

One of the key factors in the whole process of conservation is the dynamics of the formation of underwater archaeological sites. Muckelroy was one of the first researchers who devoted much attention to this process. His theory of the formation process of the underwater archaeological sites has laid the foundation to modern theories of archaeological research. (Muckelroy, 1978) Later, his concept was complemented and extended by a work of researchers who have been also very interested in the process of formation.

Among the more important works, it is important to mention the works of I.K., Ward (Ward, 1999) and Gibbs (Gibbs M.,2002) who insist on the separation of the formation process into three phases. The first phase of shipwreck or pre-deposition is the stage where a man plays a key role. The second phase or post-depositional, is conditioned by the influence of the surrounding environment, when a wreck due to various factors begins its transformation. The third, or final phase in which transformed ship's remains, together with other material remains become part of a stable natural environment. (Gibbs, 2006)(See chapter 3.1.3. Cultural site formation process)

Phase of shipwreck or (pre-deposition) can be considered as decisive for the degree of damage to the ship, which will determine its further conservation.

There are several different scenarios of a shipwreck and they very often can be very dramatic; due to the impact of underwater rocks, collision with another ship, fire, or explosion due to the combat (war) activities. In addition, shipwrecks might be less violent because of self-sinking, intentional, or unintentional stranding on the beach.[158]

For this phase, pre-depositional phase of the shipwreck, we have some very good examples from the Baltic Sea, which may confirm its importance for the conservation process. Some of the examples are the Swedish royal ship Vasa or Dutch merchant ship Vrouw Maria. In both cases, the sinking was not caused by violent destruction, and both ships were sunk undamaged at the bottom of the Baltic Sea, where they are perfectly conserved over very long period. (See chapter 5.5) It is obvious that this stage of the shipwreck has an extremely important role in the environments with high potential for conservation, such as the Baltic Sea.

However, we must ask ourselves; would there be the same result, if the same scenario occurred in the environment with less potential for preservation of underwater archaeological remains, such as the Mediterranean Sea?

It can only be supposed, but it is very probable that both ships in the environment of the Mediterranean Sea would be severely degraded or even completely disintegrated and it would ultimately collapse due to the action of wood boring organisms, primarily T.navalis, Xylophaga dorsalis, and bacteria.

It can be concluded that in the environment of the Mediterranean Sea, due to biological and physical characteristics, pre-depositional or phase of the shipwreck has much less importance for further conservation. Certainly, the following, post-depositional stage has much more important role in which biological factors, and the negative or positive effects of the sea currents have a major impact.

[158]Beltrame, C. (1996). Processi formativi del relitto in ambiente marino mediterraneo, in G. Volpe (a cura di), "Archeologia subacquea. Come opera l'archeologo sott'acqua. *Storie dalle acque", VIII Ciclo di Lezioni sulla Ricerca applicata in Archeologia.* Certosa di Pontignano (Siena), pp. 141-166.

It can be freely concluded that even in the most ideal scenario of the shipwreck in the Mediterranean Sea, only that part of the shipwreck that is well protected from the negative biological and physical factors would be preserved, beneath a thick layer of marine sediments. (Ward, Larcombe, & Veth, 1999) (Bjordal, Daniel, & T.Nilsson, 2000.) (Quinn, 2006)

Together, these negative effects lead to very rapid degradation of the ship structure. This is the reason why generally in the Mediterranean Sea only the lower part of the ship below the water line is preserved and rarely the upper parts of ship structures.

As described in the section relating to the natural processes that affect the formation of underwater archaeological sites (Ward, 1999), physical processes may not always be a cause of degradation of archaeological sites.(See chapter 3.1.2.) Very often, these processes can provide very good conditions for the conservation of wooden remains of a ship. This statement is especially true in the case where marine sediments are carried by strong sea currents, covering the shipwreck site with thick sediment. In this way, it creates a protective layer that protects the site against physical impacts and prevents penetration of oxygen. In this case, the protective layer creates anaerobic environment that prevents the presence of organisms that can cause degradation of wood materials, and conservation of natural materials, can be significantly extended. (Ward, 1999)

Submerged remains of a large merchant ship Madrague de Gains is an excellent example of good conservation of the ship structures in the Mediterranean Sea. (Picture 5.16) The ship sank between 75-60 BC during the navigation on the maritime route between central Italy and the Spanish coast. The ship was carrying a large load that consisted of 600 wine amphora type Dressel 1B.[159]

[159] Beltrame, C., *Archeologia marittima del Mediterraneo, Navi, merci e porti dall'antichità all'età moderna, Carocci editore, Roma,* (2012), pp.109-116

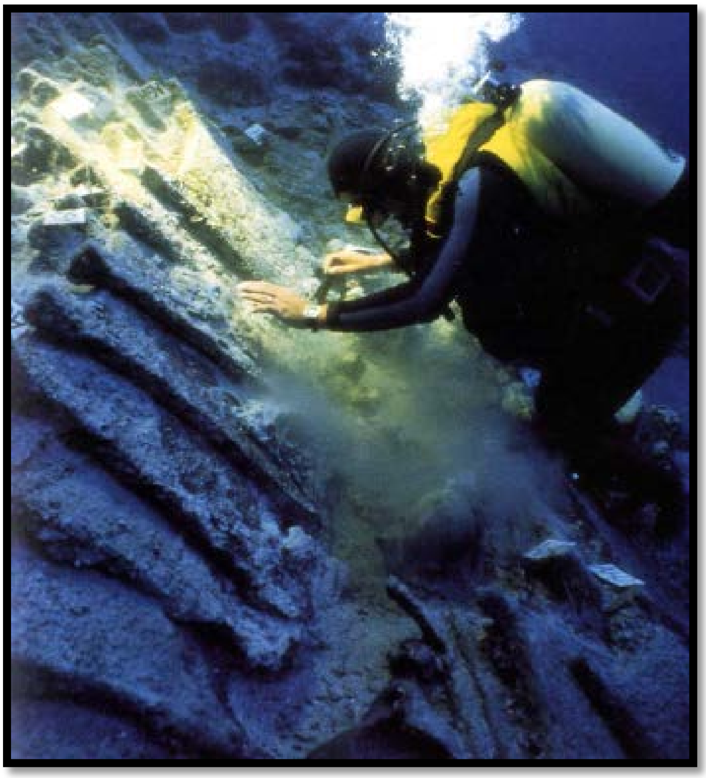
Picture 5.16 Merchant ship Madrague de Geins. A thick layer of marine sediments and algae poseidonia, has enabled remarkable conservation of the lower part of the ship's structure, together with the ship's cargo. (Photo taken from the website http://ccj.cnrs.fr/spip.php?rubrique55)

Good conservation of the ship structures, very often provides solid and non-degradable ship cargo that can be fixed and trapped by ship structure and sedimentary material. This material is more porous than the marine sediments and therefore not able to provide sufficient hermetic protection of the archaeological material as it leaves space for the flow of water and the penetration of oxygen and therefore allows for the presence of woodborers which require oxygen. On the other hand, due to its weight it provides immobility of the archaeological findings and provides additional strength of sedimentary layers, and thus provides additional protection from physical and biological impacts.[160]

Perhaps the best example that explains how ship cargo can provide physical protection of the ship structures is shipwreck UluBurun from late Bronze Age found in 1982 near the east coast Uluburun (Grand Cape) about 10 kilometres from the town of Kas in southeastern Turkey.

[160]Beltrame, C. (1996). Processi formativi del relitto in ambiente marino mediterraneo, in G. Volpe (a cura di), *Archeologia subacquea. Come opera l'archeologo sott'acqua. Storie dalle acque, VIII Ciclo di Lezioni sulla Ricerca applicata in Archeologia,* Certosa di Pontignano (Siena), pp. 141-166.

The ship has been dated to between 1450 and 1200 BC and it was carrying, among other cargo 350 ingots of copper and tin in the total weight of 10 tons. Ingots that had a square shape, were stacked at the bottom of the ship in regular rows that overlapped, such as roof shingles, in order to avoid slippage along the way. After the shipwreck, the ship was, probably due to the high weight of cargo, deposited on the bottom in a very short period of time where it remained preserved under layers of cargo and thick layers of sediment.[161] (Picture 5.17)



Picture 5.17 Ulu Burun ship carrying 10t of copper and tin in the form of 350 ingots identical shapes, which were properly arranged at the bottom of the ship. After shipwreck, heavy ship cargo provided excellent stability and conservation of the wooden hull. (Photo Bass, 2005, pp.37.)

Type of cargo can be different, for example, a heavy stone or marble blocks, sarcophagi, or ship cannons that were placed on the flanks (sides) of the ship.

[161] Bass, F. George, *Beneath The Seven Seas*, Thames & Hudson Ltd, London,(2005), pp. 34-47

After the shipwreck, these guns can be an effective protection of a small part of the ship structure. Particularly interesting cases are the late medieval ships that as the part of the ship construction had a certain amount of stones that served as ballast aboard. After shipwreck, these piles of rocks provide very good protection for the ship's construction against physical impact. It is important to note that these piles provide a very good basis for marine sediments trapped between rocks, hermetically covering the ship's structure or one of its larger parts, providing long lasting protection. (Beltrame C. ,1998)

This is precisely the case with the Venetian merchant ship from 16th century that was discovered on the site of St. Pavle, on the south side of the island of Mljet in Croatia. (Picture 5.18)

Picture 5.18 Venetian merchant ship from 16th century from the site of St. Pavle discovered on the south side of the island of Mljet (Croatia). Photo shows the lower part of the ship construction, which is very well preserved beneath a thick layer of rocks and marine sediments. (Photo Robert Moskovic, photo documentation of HRZ, Zagreb)

The shipwreck is located at a depth between 36-46m and there was recorded a lot of different archaeological materials. Certainly, the most important discovery were seven bronze cannons that were made in four different sizes and a large number of ceramic findings of high aesthetic value that had been produced in Iznik (Turkey). These dishes were probably intended for the Venetian market. Before the beginning of the archaeological works, the ship construction was under sedimentary layers, and it was not visible.[162]

Well-preserved remains were only the lower part of the hull and much of it was covered with a pile of river stones with marine sediments, which provided a very good conservation.

Visual analysis in-situ determined that a small part of the structure that was lying under the thin layer of sediment, had traces of damage caused by wood boring organisms.

It is assumed that this part of the ship structures had repeatedly been completely uncovered and unprotected due to strong hydrodynamic energy, which is very pronounced in this area and at this depth. South side of the island is facing the open sea and it is more exposed to sea currents that can be very strong due to meteorological perturbations.

This example, and others that were previously mentioned, confirmed that the wooden remains of shipwrecks can be hard degraded or completely destroyed due to the impact of wood borers and the abrasive action of sea currents, if left unprotected. This fact provides strong evidence that the environment of the Mediterranean Sea generally do not provide good conditions for the conservation of wooden archaeological remains of shipwrecks and other objects made of natural materials.

When we speak of inorganic materials, the situation is much more favorable, especially in the case of ceramic or metal findings. If they are protected from, physical impacts, primarily from the erosive and abrasive effects of sea currents, their conservation can be a very good and long lasting. It is important to note that very often; an underwater archeological shipwreck site can be very complex in its composition and the range of material that can be found on it.

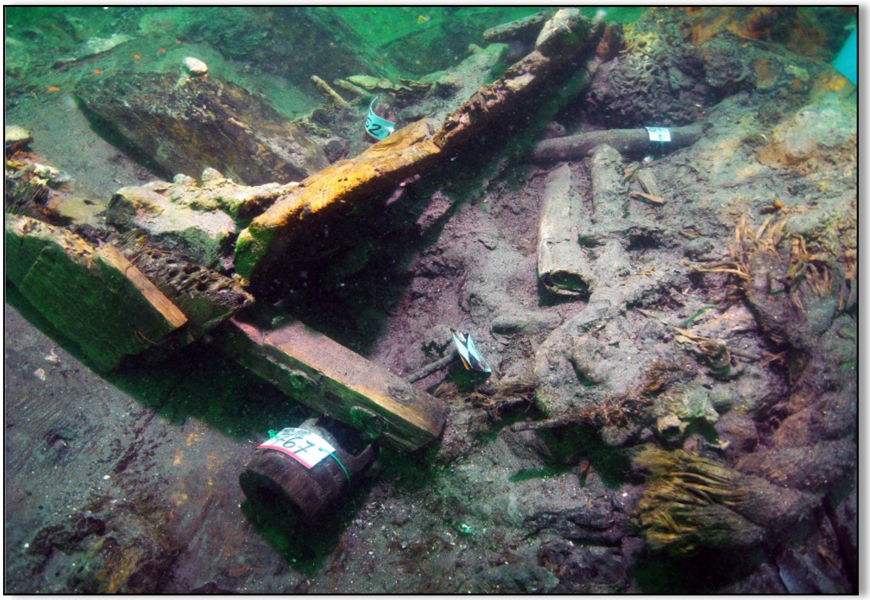
[162]Miholjek, I.,Novovekovni brodolom kod plicine Sv.Pavao pokraj otoka Mljet, *Jurasicev Zbornik*, Hrvatski Restauratorski Zavod, Zagreb, (2009),pp.272-283.

In very few cases, the environmental conditions may be equally good for the conservation of different materials. One of these cases is shipwrecked.

As in many cases with well-preserved shipwreck, also in this case was found a very large number of different and very well-preserved archaeological material. Great value of these archaeological findings comes from the fact that it is possible to connect all with the time before the sinking of the ship. In other words, the crew used all objects that were being found, every day, and these facts are of the great help because it allows the reconstruct the life and activities on board.

Mercury is a warship that was sunk in the northern Adriatic Sea (Punta Tagliamento), during the naval Battle of Grado, 21 February 1812. The historical facts relating to the entire naval battle and the sinking of the ship are very controversial and unreliable, because each side to the conflict had its own version of events and its interpretation. However, the main cause of the sinking of the ship was a powerful explosion that was been recorded after the first analysis of the hull during archaeological research. After the explosion, the ship has been divided into two major parts. Prior to the final sinking, parts of the ship floated some time scattering boat equipment, after they are deposited on the seabed to a distance of about 70 meters.

It is assumed that the ship remains on the sea floor were covered and filled within marine sediments in a relatively short period. As mentioned previously (chapter 5.6.1.2.), this area is characterized by relatively strong currents and large amount of sediment that reaches the sea Carried by numerous rivers that flow into the Mediterranean Sea in that area. This natural protection against environmental impacts enabled the remarkable conservation of archaeological material. The wooden structure of the ship, which has been systematically explored, was in unusually good condition for the conditions of the Mediterranean Sea. The collected data gave additional information on the ship's construction of military ships of the time. (Picture 5.19)



Picture 5.19 The remains of the ship's hull of military ship Mercury. (Photo Stefano Caressa, archaeological photo documentation, University Ca'Foscari, Venice)

During several archaeological campaigns undertaken within a period of several years, were found many different archaeological artifacts.[163] Were found various kinds of guns that made up the ship's weapons and were in accordance with military standards for that period the, as well as several pieces of personal firearms, pistols and rifles, as well as a couple of very interesting findings of a large-caliber rifles and short-barreled. (Picture 5.20).

Have been found numerous objects of metal that made up the parts of ship structures especially large nails and wedges that connected and reinforced parts of the ship, copper and lead lining to the hull. Common findings were items that were an integral part of the sail as the various pulleys, bigots, grappling hook, kedges tip.[164]

[163] Beltrame, C., Gaddi,D.,(2002),Report on the first research campaign on the Napoleonic brick, Mercure, wrecked off Lignano, Udine, Italy in 1812, *The International Journal of Nuutical Archaeology 31.1,* pp.60-73

[164] Beltrame, C., Elementi per un'Archeologia dei Relitti navali di età moderna; L'Indagine di scavo sottomarino sul Brick Mercurio, *Missioni Archaeologiche e progetti di Ricerca e Scavo, VI Giornata,* (2008), pp. 219-227

Picture 5.20 Very well preserved pistol that was part of the personal armament of the crew (photo Stefano Caressa, archaeological photo documentation Ca'Foscari University, Venice)

Excellent conditions for the conservation of the shipwreck are confirmed by the large quantity of parts of military uniforms and other garments. Were found many different types of buttons and various decorations that were part of the military uniform.

In addition to the fascinating archaeological material, that was found at the site during the archeological excavations, it was found several human skeletons and these findings are classified underwater archeological site Mercury among the rare sites where human remains were found.[165]

The cause of death of a large number of crewmembers was a powerful explosion that ultimately led to the sinking of the ship. During the depositing of the ship to the bottom, the remains of fallen sailors were trapped in the interior of the ship, where they remained until archaeological excavations.

[165] Bertoldi, F., I resti osteologici umani, in C*aorle archeologica Tra mare, fiume e terra*, Fozzati L.,(2007), pp.147-149.

It is assumed that the rapid sea sediments covering of the entire shipwreck and penetration and deposition of sediments in its interior, the reason for the good preservation of skeletal remains and other archaeological materials.

Underwater archaeological sites that containing human remains and skeletons are very rare, and some authors believe that the underwater environment and saltwater are not good conditions for the conservation of skeletal material and that a bone is rare because of poor conservation. [166]

However, studies dealing with the chemical analysis of human bones that were found at underwater sites suggest exactly the opposite conclusion. This research has shown that levels of calcium and phosphorus remains stable even after a long time spent on the seabed and the structural changes of bone minimal, even negligible. In addition, low and constant temperature, low oxygen, and a neutral pH value, otherwise the characteristics of the marine environment, provides excellent conservation of skeletal material. [167]

From this example we can conclude that the inability of good conservation is not the reason for the rare discovery of human bones at underwater sites.

One logical explanation could be that after a shipwreck, most of the crews trying to rescue. Those less fortunate, usually are taken away by sea currents, or remain trapped in the interior of the ship or tangled in the ropes. Subsequently, after the collapse of the ship's construction, human remains can be released and moved to another place.

Another important prerequisite for good conservation of human remains and recorded coverage of shipwreck layer of marine sediments.

These sediments will also create an anaerobic environment suitable for the conservation and immobility of human remains and skeletons.[168]

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[166] Foreman, L., Phillips, E.B. and Goddio, F., Napoleon's Lost Fleet: Bonaparte, Nelson and the Battle of the Nile, New York, (1999), pp. 140-141

[167] Arnaud, G., Arnaud, S., Ascenzi, A., Bonucci, E. and Graziani, G., 'On the Problem of the Preservation of Human Bone in Sea-Water', *The International Journal of Nautical Archaeology 9.1* (1980), pp.53-65.

[168] Gregory, D., 'Experiments into the Deterioration Characteristics of Materials on the Duart Point Wreck Site: an Interim Report', *The International Journal of Nautical Archaeology 24.1* (1995), pp.61-65.

Such conservation has been the case in the shipwreck Mercury and for this reason it was possible to find a large number of skeletons.

Human remains and skeletons, observed in terms of archaeological evidence, are of great importance and one of the archaeological evidence that can give a lot of information necessary for the reconstruction of a historical event or for the creation of an archaeological context. However, the investigation of human remains withdrawn a number of ethical issues that require archaeologists to treat them in a different way unlike other archaeological finds. In addition, for ethical reasons, it is understood that the human remains should not be disturbed without reason. (see chapter 2.1.3 Memorial significance)

However, it is important to note that most of the examples of human skeletons on the shipwreck site belong to group catastrophe samples, which includes events where a large group of people lost their life in the same way in a very short time. This category includes naval battles and shipwrecks, which can result in loss of human life. These catastrophic events also require research and discover the reasons that cause a loss of human life.[169]

We can conclude that the research and analysis of human remains from underwater archaeological sites has great archaeological potential and importance for a better understanding of life on board as well as for the reconstruction of certain historic events. Osteological analysis in laboratory can provide excellent information of great importance.

For example, it is possible through DNA analysis to determine the ethical[170] and social[171] association of sailors who lost their lives. Such an analysis has been carried out on the remains found on shipwreck Mary Rose and battleships Vasa.

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[169] Mays, S., Human remains in marine archaeology, in *Environmental Archaeology vol. 13 no.2* ,(2008), pp. 123-133

[170] During, E. M. The skeletal remains from the Swedish man-of war Vasa — a survey. HOMO— *Journal of Comparative Human Biology 48,* (1997b). pp.135–60.

[171] Stirland, A. Human remains, in Gardiner, J., Allen, M. J. (eds.) *Before the Mast: Life and Death aboard the Mary Rose (The Archaeology of the Mary Rose, Volume 4)*, Portsmouth: Mary Rose Trust, (2005), pp. 516–44

In addition, a detailed analysis of skeletal remains or fragments, it is possible to determine the physical and medical condition[172] and any injuries and deformities caused by injury or over-exertion[173], among the members of the crew. Osteological analysis of the shipwreck Mercury determines the age group of the ship's crew and in some cases, diseases, and deformities. Bearing in mind that this type of analysis has a large archeological and scientific potential, future research could be aimed at determining the ethical background of the crew and their origin.

[172] Nuorala, E., Tuberculosis on the 17th century man-of-war Kronan, *International Journal of Osteoarchaeology 9,* (1999) pp.344–348.

[173] Rogers, J. The paleopathology of joint disease, in Cox, M. and Mays, S. (eds.), *Human Osteology in Archaeology and Forensic Science*. Cambridge University Press. (2000), pp. 163–82

5.6.1. SPECIFIC CONTEXTS OF DEPOSITION

In the area of the Mediterranean Sea, there are several different contexts, or the specific environments in which an archaeological shipwreck site can be formed. Each of these areas has some specific characteristics that determine the degree of conservation of archaeological material. These specific environments are characteristic of all seas and oceans of the world, not just the Mediterranean Sea. What makes an essential difference between them all, is the potential of these environments for the formation and conservation of archaeological sites. This potential depends largely on the geographical and physical characteristics that are unique to each region of the world.

5.6.1.1. DEEP SEA

Until a few decades ago, the researches of underwater archaeological sites in a deep sea, have been based on theoretical foundations based on research that had a very big limitations in the methodological approaches, because they lacked the technological achievements. With the development and use of the latest technology, underwater archaeologists are allowed to go down and explore great depths. Since then the number of known sites that had previously been unknown or inaccessible has significantly increased. (Picture 5.21)

In the last decade, several projects were conducted aimed at investigating the remains of shipwrecks at great depths in the Mediterranean and Black Sea. These projects are important because they represent the collaborative work between archaeologists, geologists, and biologists. Such a multidisciplinary approach is very fruitful, if not obligatory because only in that way it is possible to expand the knowledge relating to the formation and conservation of underwater archaeological sites in a deep sea but also on other underwater terrains.

Picture 5.21 The Jason ROV recovering an object from the Isis shipwreck site during the 1989 project. The wreck dates to the 4th century A.D. Field Projects - Skerki Bank1989-2003(Photo taken from the website http://www.whoi.edu/sbl/liteSite.do?litesiteid=2740&articleId=4418)

For a long time, there was an opinion that the environment at great depths of the Mediterranean Sea, was a very good place for the formation and conservation of underwater archaeological sites because the hydrodynamic energy is much weaker as opposed to surface water.

This statement is completely true because hydrodynamic energy and erosive effect caused by sea currents, significantly loses its strength asdepth increases and already at depths below 50m, this effect is minimal but it still exists.

Another reason is that with increasing depth the amount of dissolved oxygen in the water significantly decreases which is necessary for the development of certain types of wood boring organisms that could cause degradation. However, at depths below 200m there are no conditions for settlement of T.navalis.[174]

[174]Beltrame, C. (1996). Processi formativi del relitto in ambiente marino mediterraneo, in G. Volpe (a cura di), *Archeologia subacquea. Come opera l'archeologo sott'acqua. Storie dalle acque, VIII Ciclo di Lezioni sulla Ricerca applicata in Archeologia,* Certosa di Pontignano (Siena), pp. 141-166.

However, recently implemented projects in the Mediterranean Sea proved the presence of wood boring bivalves Xylophaga dorsalis and bacteria at very great depths. (see chapter 5.3.3. Case studies in Mediterranean Sea). These findings show that the risk of wood boring organisms exists in almost all parts of the Mediterranean Sea, and even in great depths.

Two other very interesting projects aimed at exploring the great depths of the Mediterranean Sea were Skerk Bank Project (1989-2003)[175] and Project Ashkelon Phoenician wreck (1999)[176]. These projects have made a very big contribution to understanding the process of the formation of archaeological sites at greater depths.

During these studies, using the most advanced devices and technologies, several shipwreck from different epochs were documented. Perhaps the two best examples are two shipwrecks (Tanit and Elissa), which were discovered in 1997 near the Israeli coast, at the depth of 400m. A detailed analysis revealed that these two Phoenician ships dated from the period around 800 BC. The size of ships is also similar. Bearing in mind that over the time the structures of the ships completely disappeared, the calculation of dimensions of the hull was committed in both cases, surveying the ship's cargo. Based on these data, it was calculated that the ship Tanit (Picture 5.22) was 14m long and 6.5m wide, while the other ship Elissa was a bit bigger and 14,5m long and 7m wide. Positions where the remains of these ships were discovered, led researchers to a conclusion that they were on an antique navigable route that linked Ashkelon with Egypt and Carthage. (Ballard et al. 2002)

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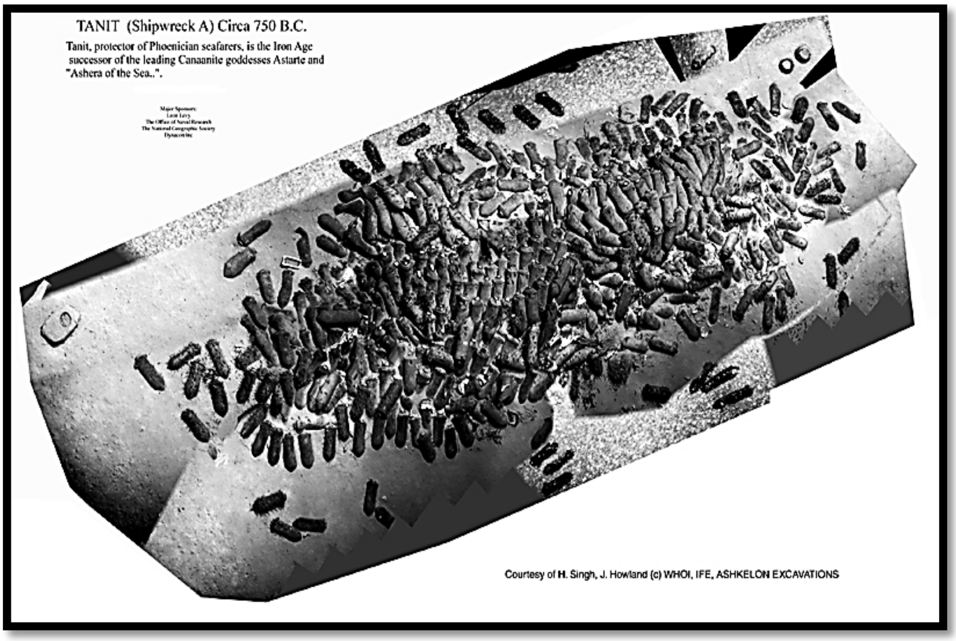
[175]McCann,A.M. and Oleson,J.P.,Deep-Water Shipwrecks off Skerki Bank: The 1997 Survey, Journal of Roman Archaeology, Suppl.Ser.58, Portsmouth, R.I.: JRA, 2004,

[176]Robert D. Ballard, Lawrence E. Stager, Daniel Master, Dana Yoerger, David Mindell,Louis L. Whitcomb, Hanumant Singh and Dennis Piechota, Iron Age Shipwrecks in Deep Water off Ashkelon, Israel, *American Journal of Archaeology,Vol. 106, No. 2* (Apr., 2002), pp. 151-168



Picture 5.22 Photo shows photomosaic of merchant shipwreck "Tanit" the 8thcentury BC Phoenician wrecks. (Photo taken from http://www.whoi.edu/sbl/liteSite.do?litesiteid=2740&articleId=5018)

In the case of both ships Tanit and Elissa, remains of the ships along with the ships' cargo were found in a small depression in sand bottom, while their content was uncovered and fully exposed to environmental influences. This is the main reason why the ships' structure is not conserved.

Another similar example is the ship Skerki D (Picture 5.23), which was found during Skerki Bank project which is located at the ancient route Carthage Ostia. During this project several shipwrecks were found from different periods;fromthe Roman period to the period of the 19th century. (McCann & Oleson, 2004)

Notwithstanding the considerable distance between the archaeological sites Skerki D and Tanit and Elissa, they are very similar in their formation and the degree of preservation.

Generally, in all cases, the ship cargo was visible and exposed to environmental influences and the wooden structure over time completely disappeared. It is assumed that the lowest part of the hull could be preserved under the cargo and sediments.

Picture 5.23 Photomosaic of remnant cargo assemblage on the Skerki D shipwreck. The wreck dates to the 1st century B.C. (Photo taken fromhttp://www.whoi.edu/sbl/liteSite.do?litesiteid=2740&articleId IFE, Hanumant Singh, Skerki 2003)

It may be concluded that at great depths of the Mediterranean Sea it comes to the degradation and destruction of wooden material due to wood boring organisms that live in the environments with extremely reduced amount of oxygen, primarily Xylophaga d. and certain types of bacteria. After the upper part of unprotected and already degraded wooden structure is removed, the process of degradation of ship remains additionally accelerates due to horizontal hydrodynamic energy at the bottom which is also very weak but constant.

After the upper part of the wooden structure is disintegrated, water currents cover non-biodegradable contents of ship cargo.

Over very long periods, the horizontal current gradually removes the surface sediment revealing the wooden parts that will be gradually destroyed. This slow process takes a long time until just artefacts remain firmly attached to the bottom.[177]

All these facts clearly suggest that the environment of great depth in the Mediterranean Sea is very good for the conservation of artefacts of solid material such as amphorae. On the other hand, it does not provide good conditions for the conservation of wooden material. When considering the problem of formation of archaeological sites, it can be concluded that in this environment vases similar rules as on the lower depths, the difference is that this process lasts longer in the deep due to the slow hydrodynamics.

[177]Ballard R.,D., Lawrence E. S., Master D., Yoerger D., Mindell D., Whitcomb L. L., Hanumant S. and Piechota D., Iron Age Shipwrecks in Deep Water off Ashkelon, Israel, *American Journal of Archaeology, vol. 106, no. 2,* (Apr., 2002), pp.164-165

5.6.1.2. SHALLOW WATER AND BEACHES

Beaches are very dynamic land formations, which constantly rise and change their appearance due to wind, waves and sea currents in a continuous cyclic process of depositing sedimentary and erosion materials.

The process of beach formation begins with the erosion of continental material; earth, sand, gravel, which arrive in a sea carried by streams and waterways. One part of erosive material can be deposited directly on the coast, and the other is dissolved in the water in the form of fine suspensions transported with the water currents parallel to the coastline due to high hydrodynamic energy. Depending on its intensity and energy, currents can potentially transfer large amounts of gravel, sand and fine sediment. In some extreme cases, marine currents can bring millions of cubic meters of erosive materials along the coastline.

However, the process of beach formation does not end; transport and re-deposition of sedimentary material can proceed further. Due to the impact of waves and its constant forward and backward movement, sediment is deposited on the beach, it can be subsequently moved from its place and re-enveloped and carried away by currents, and deposited in another remote location.

Deposition of sedimentary material and its transport depends on several factors, primarily on the season, weather conditions, and the influence of man.

The process of creating a beach on the Mediterranean Sea is similar to any other region in the world because the same mechanisms operate in the process. However, they are very characteristic areas where this process is more pronounced in comparison to others.

A typical example are the coast of the northern Adriatic Sea and the coast of Israel in which there are characteristic regional sea currents and large river basins that bring large amounts of sedimentary material; Alpine river basin and basin of the river Nile. (See chapter 5.2.4. Currents in the Mediterranean Sea)

The formation of archaeological site and its subsequent conservation on the beach is a very complex process. This comes from the fact that the environmental conditions on beaches and coastal zones are very specific and characterized by extremely high hydrodynamic energy caused by the action of waves and currents. [178]

The general opinion is that these places do not provide good conditions for the formation of archaeological sites and especially for their conservation. However, because of very high hydrodynamic energy, very often a shipwreck can be very well preserved in these conditions. The main prerequisite for this is that the ship's remains must be covered with gravel and sediment in the shortest period, creating the physical protection of the ship structures and other archaeological material from the negative impact of hydrodynamic impacts of coastal sea currents and waves as well as biological factors.[179]

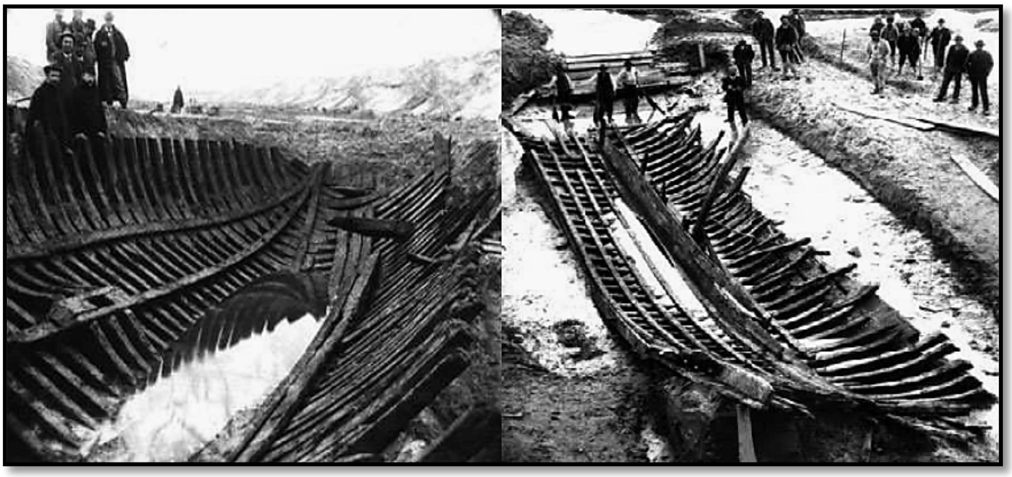
In the area of the Northern Adriatic Sea, specifically, in the delta of the river Po, a few remnants of a ship hull were found that were very well preserved in beach environment.

One of the most famous sites is Contarina near Rovigo (Italy), where the remains of two ship hulls were discovered, Contarina 1 and Contarina 2 that were located in the immediate vicinity.

These accidental discoveries from 1899 during construction works and excavation of an artificial canal near Rovigo, initiated, in the following year, the research and development of archaeological documentation as well as raising the ship with the intent to transport and conserve it in Venice. (Picture 5.24)

[178] Beltrame , C., Investigating Processes of Wreck Formation: Wrecks on the Beach Environment in the Mediterranean Sea. *Archeologia subacquea. Studi, ricerche e documenti vol.3*, curato da Gianfrotta P. A., Pelagatti P. (2002), pp. 381-398.

[179] Beltrame, C. (1996). Processi formativi del relitto in ambiente marino mediterraneo, in G. Volpe (a cura di), *Archeologia subacquea. Come opera l'archeologo sott'acqua. Storie dalle acque, VIII Ciclo di Lezioni sulla Ricerca applicata in Archeologia,* Certosa di Pontignano (Siena), pp. 141-166.



Picture 5.24 Locality Contarina (Rovigo, Italy). During the construction works have been found the remains of two ship's hull (1899); (right) Contarina 1; (left) Contarina 2

From the documentation that is preserved, we find that the ship Contarina 1 was a boat with a flat bottom, 19.50m long 5.2mwide. Both ships are from the Middle Ages. Based on the ceramic findings that were found with the ship Contarina 2, this ship can be precisely dated to the second half of the 15th century. Based on where ship Contarina 1 was found, it can be assumed that both ships are from similar period. The ship Contarina 1 is located a few hundred meters away from ship Contarina 2 and is more distant from the coast. Keeping in mind the expressed movement of the shoreline in the Middle Ages it can be assumed that the ship Contarina 1 is a little older.

These were very important findings for several reasons, primarily because they made an outstanding contribution to the study of the history of shipbuilding in the Mediterranean. Second, these findings made a great contribution to the study of geomorphological processes of creation and movement of the coastline in the northern Adriatic. The third important reason is that they represent pioneering research in Italy in the field of underwater archaeology.[180]

[180] Beltrame, C., in *Archeologia marittima del Mediterraneo, Navi, merci e porti dall'antichità all'età moderna*, Carocci editore, Roma, (2012), pag.39-58.

In addition, it is worth noting that few more residues of ship structures were discovered in this area. Primarily ship Logonovo near Ferrara, the remains of the ship in Borgo Caprile, as well as parts of a ship hull at Porto Fuori near Ravenna.[181]

Probably the best example, which could explain the phenomena of shipwreck sites in shallow water and on a beach, is Laguna Tantura in Israel. This lagoon is one of few natural harbors and protected anchorage along the entire coast of Israel, which is very flat and shallow. (Picture 5.25) Over this very limited space, seven different remains of ship hulls were discovered. Due to a large number of shipwrecks that are located on its bottom, this lagoon is famous as "The Graveyard of Ships”. [182]

Picture 5.25 This aerial photo shows the excavation of the Tantura B shipwreck in extremely shallow water. Underwater photographs show parts of the hull Tantura B (photo George F. Bass,(2005), pag.99)

The most important and certainly the best researched and documented were Tantura A, Tantura B, (Bass, 2005.) and Tantura F. [183]

[181]Beltrame., A New View of the Interpretation of the Presumed Medieval Po Delta Wrecks, Italy, *The Nautical Archaeology Society,*(2009), pp.412-417

[182]George F. Bass, *Beneath The Seven Seas*, Thames & Hudson Ltd, London,(2005),pp.98-99

[183]Kahanov,Y., Barkai, O., The Tantura F Shipwreck, *The International Journal of Nautical Archaeology,* (2007)36.1, pp. 21–31

After the analysis in-situ, the first results showed that Tantura A has the length of 12m that are slightly smaller dimensions compared to the average length of a ship of the period. For this reason, it is assumed that it was made in local workshops, and served for shorter navigational routes.

The shipwreck Tantura B was found just a few meters away from Tantura A. Analysis showed that the ship was of little larger dimensions and it was dated to the period of 9th century AD. The shape of its hull points to its Andalusian Arab origin and was probably used for the Arab conquest of the Mediterranean islands 824 AD. (Bass, 2005)

The rest of the ship hull Tantura F was located at the depth of only 1 m, below 1.5 m thick layer of marine sand. Based on the analysis of C14 the ship is dated to the period at the beginning of 8th century AD. (Kahanov & Barkai (2007) 36.1 :)

Regardless of the structure, purpose, and origin, all the ships that were found in Tantura lagoon share a common feature that they had had a traumatic end and sank in an effort to reach the shelter during storms before they were broken against the rocks and sank. After their sinking, probably large parts of their ship construction were covered with a thick layer of sand in a very short time due to the high hydrodynamic energy of sea currents, which also provided exceptional preservation.

Also another very good example of good preservation and conservation of marine structures is the discovery of the Phoenician merchant ship that was found in the waters Ma'agan Micha'el, 30 km south of Haifa in Israel, at the depth of 2-3 m at the distance of 50m from the shore.

The remains of the ship are from the period of 5-6 century BC. In addition, this shipwreck is considered the best-preserved hull of the time. (Picture 5.26)

Picture 5.26 Aerial photo shows the coast of Ma'aghan Micha'el where they were discovered the remains of the Phoenician merchant ship.

The above examples suggest that, in the Mediterranean, there is a great potential for the formation of underwater archaeological sites in the environment of shallow coastal waters and beaches, as well as for their very good preservation. Unfortunately, these coastal areas are at the greatest risk from the effect of man's activities.

Construction works are very often threatening these sites and lead to their destruction. In order to protect the coastal sites, it is necessary to use all legal instruments and well-known techniques of conservation in order to protect these valuable archaeological remains.

5.6.1.3. ROCKY BOTTOM

From the previous examples, it can be clearly concluded that between the formation of archaeological shipwrecks site on the seabed and environmental factors, there is a strong correlation, and these factors represent a decisive influence for the further process of preservation[184] and one of the crucial preconditions for the conservation is the composition of the seabed.

On the stone seabed of the Mediterranean Sea, sand and sediment deposits can very rarely be found, which are necessary for the physical protection of archaeological remains and the basic prerequisite for the conservation of material. For this reason, we can conclude that rocky bottom does not provide optimal conditions for good conservation.

The organic material in these conditions is rapidly degraded due to biological and physical impacts. On the other hand, inorganic archaeological materials can survive in this type of seabed but can be very often damaged due to strong hydrodynamic energy of marine currents coupled with the waves. This is especially often the case with ceramic archaeological material that can be very fragmented due to friction so that sometimes it is impossible to identify and reconstruct the parts that were found. By analyzing and prospecting such sites, it may be noted that the material is scattered in the wider area and is therefore very difficult to connect the archaeological findings in a logical context.

In addition, a very common occurrence on these sites is the encrustation of archaeological material that occurs due to activities of marine organisms and it highly depends on the physical and chemical properties of seawater. The result of the whole process is the coating of archaeological material with solid and a thick layer. Very often, the material remains are permanently fixed to the rocky sea floor.

[184] Muckelroy, K., *Maritime archaeology*, (1978), pp.160-165

Underwater archaeological sites that are located on rocky bottom are very often on the northern coast of the Mediterranean, especially on the Croatian Adriatic coast, where the rocky sea floor is the main feature.

Examples of this type are archaeological sites near the Cape of Uljeva.[185]These sites are located to the south of the bay of Kuje at Ližnjan (Pula, Croatia) and are open to the impacts of strong wind from the south, especially to the very strong wind from the north. Although the site was discovered in the early 80s of the last century, the first real archaeological reconnaissance of the two shipwreck sites off Cape Uljeva was carried out in 2008.[186]

During reconnaissance of the underwater terrain, it was found that the Uljeva A shipwreck is located in the shallower part at the entrance to the bay, Kuje. The site is located at a depth of about 4-8 m, and covers an area of over 100 m2. According to previous research, it can be concluded that the site contains the remains of a large Uljeva A ancient ship with a cargo of amphorae from the period between 1st century BC and 1st century AD. (Picture 5.27)

All intact amphorae and neck of amphorae were looted by the time of the discovery of archaeological sites. The rest of the amphorae that were scattered over the rocky bottom of the bay is obviously very damaged due to the influence of sea currents and waves, and scattered through the channels between the larger rocks. The dominant type of amphorae appears to be Lamboglia II, although there are also other types of amphorae. Some of the fragments of amphorae were not possible to identify due to severe damage. Numerous amphorae stoppers indicate that the amphorae were full at the time of the shipwreck.

[185] Bekić, L., Najnovija podvodna rekognosciranja podmorja Istre, Histria Antiqua 21, Pula, (2012b), pp 581-597.

[186]Miholjek, I. - Akvatorij Istre, Hrvatski arheološki godišnjak 5/2008, Zagreb, (2009), pp.309-311.

Picture 5.27 Archeological site Uljeva A.; Production of archaeological documentation - Underwater archaeologists sketch the cut in the rock bottom of the sea filled with the remains of ancient amphora (photo documentation ICUA, Zadar September 2013)

About 150 m to the south, but still in the same location, there is another wreck called Uljeva B. Its location is hard to spot because it was not carrying that amount of amphorae. However, by carefully searching the bottom a large number of typologically definable parts of amphorae were found, especially the throat and handle.

These characteristics reveal that it was the ancient Roman shipwreck that carried amphorae of African production. The predominant type of amphorae is type Keay 3B (T.6-6) but there were also found the fragments of amphorae Keay 26 or so called Spatheion amphorae (T.6-4). In addition, a large part of the cargo is kitchenware of so-called Aegean type. Numerous fragments of pots and cups of this kind of Ceramics were found. Based on the collected findings, this shipwreck could be dated to the period of 4th century AC.

As in the case of a shipwreck Uljeva A, all archaeological material is scattered in a wide area of the rocky seabed.

Despite severe damage due to erosion caused by sea currents and waves, some less damaged items were collected for the preparation of reconstruction of the amphora in laboratory conditions.

Characteristics of these sites are deep cuts and channels between the big rocks. These channels sometimes may contain small amounts of sediments that are insufficient to cover and protect the archaeological material. However, these channels can provide protection from strong currents and thus partially mitigate all their negative effects. Certainly, this protection will not have a greater impact in case where the archaeological material lies at the bottom for a very long period of time as is the case in localities Uljeva A and B. (Picture 5.23)

Examples of these underwater archaeological sites only confirm the previous conclusion that the stone environment and rocky bottom do not provide good conditions for preservation and conservation of archaeological material.

6. A PLANNING MODEL AND METHODS FOR THE PROTECTION OF ARCHAEOLOGICAL SITES IN-SITU

The area of the Mediterranean Sea contains an extremely large and important cultural and historical archaeological heritage. Thousands of wrecks from different epochs lie on its bottom. Unfortunately, at the time of discovery of by underwater archaeologists, the vast majority of these shipwrecks are in a state of relative devastation. The main reasons for their poor state of conservation are environmental conditions and the impact of man. As discussed in the previous sections, the Mediterranean Sea provides very limited conditions for natural conservation of archaeological remains. On the other hand constant looting of underwater archaeological sites and their destruction due to human activities, also present a big problem. Very rarely, does the discovery of completely undamaged ships. These finds, in addition to all their excellence, bring several problems related to ethical issues and methodological approach to the research and future of conservation of the shipwreck. If such a wreck, is left on the seabed without any protective works, it is a question of the time when it will be looted and destroyed. In the case of comprehensive archaeological work, a large amount of archaeological material requires great elaboration. This primarily involves the conservation of materials and its storage in an appropriate space. Unfortunately in many cases the lack of adequate funds and museum space, also present a big problem. All the above problems are a challenge for modern archeology.

It can be concluded that it is necessary to design a new innovative methodological approach, which would also enable quick and easy protection and conservation, the possibility of periodic surveys and monitoring and be cheap.[187]

The solution for this complex situation is the application of methods of in-situ conservation of the archaeological shipwreck site.

In-situ conservation, ideally, can be a completely spontaneous natural process that will provide good conditions for preservation.[188] There are many good examples of natural conservation in-situ from the area of the Baltic Sea. However, such cases are generally rare and for this reason professional intervention is necessary, in order to ensure permanent protection of shipwreck sites.

Application of in-situ conservation involves the use of several different methods in order to provide the physical protection of shipwreck sites from negative environmental influences, thus completely slowing down the degradation of archaeological materials and enabling long-term protection and conservation. In addition, in-situ conservation is a non-invasive method that allows the preservation of the integrity of the shipwreck site, which means that this method does not envisage the movement of archaeological material from its original place. This is very important because, due to displacement and dislocation, archaeological material could lose its original context, which means the loss of valuable information.

Another big advantage of this method is that conserved and fully integrated shipwreck site remains available to future generations and for future scientific researches.

[187] Mario J., La protezione fisica dei siti archeologici sommersi del fondale marino nell'Adriatico Croato, in *Archeologia subacquea in Croazia*, in cura Irena Radic Rossi, (2006),pp.147-156.

[188] Delgado, J. ,In-situ conservation, in(ed.) *Encyclopedia of underwater and maritime archaeology*, British Museum Press, London, (1997), pp. 233-235

Finally, in-situ conservation is a very cheap and very effective method of protection that enables quick setup of protection but also its removal in case of periodic monitoring or archaeological research.

On underwater archaeological sites, there are often limiting factors that do not allow the intervention. In these cases, the archaeological material can be excavated from the site and subsequently transferred to a secondary location. This method of in-situ storage is applied near the primary site at the secondary site previously prepared to provide better conditions for conservation. [189]

Over the past few decades, in-situ conservation and in-situ storage has become the main option for the preservation of archaeological sites.[190] In this period several projects were carried out which aimed at investigating and comparing the protective effect offered by the natural sediment in relation to the subsequent layer set.

Noteworthy projects that were implemented in Northern Europe and Scandinavia were RAAR (Reburial and Analyses of Archaeological Remains)[191], MoSS Project (Monitoring, Safeguarding and Visualizing North-European Shipwreck Sites)[192], and SAS Map Project. Positive results from these projects show that in-situ protection and conservation, is a very effective method to protect underwater archaeological cultural heritage.

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[189] Holden, J., West, L.J., Howard, A.J., Maxfield, E., Panter, I. & Oxley, J. 2006, Hydrological controls of in situ preservation of waterlogged archaeological deposits, *Earth-Science Reviews, vol. 78, no. 1-2,* pp. 59-83.

[190] Babits, L.E. & Van Tilburg, H., *Maritime archaeology: a reader of substantive and theoretical contributions*, Plenum Press, New York; London. (1998), pp. 590-593

[191] Bergstrand, T. & Nyström Godfrey, I. (eds) 2007, Reburial and analyses of archaeological remains: studies on the effect of reburial on archaeological materials performed in Marstrand, Sweden 2002-2005. *The RAAR project,* Bohusläns Museum and Studio Västvensk Konservering, Uddevalla.

[192] Cederlund, C.O. (ed.) (2004), *Monitoring, safeguarding and visualizing North-European shipwreck sites – challenges for cultural resource management: final report,* The National Board of Antiquities, Helsinki.

For this reason, this method is often applied in many locations around the world and is considered the first option when planning the protection of the site.[193]

[193] Godfrey, I. M., Gregory, D. Nystrom, I., Richards, V.,. In Situ Preservation of Archaeological Materials and Sites Underwater. Fabio Maniscalco (ed.), *Mediterraneum, Vol.4.* (2004)pp. 343-351.

6.1. IN SITU CONSERVATION AND STABILIZATION

The main prerequisite for the long-term in-situ conservation is to stabilize the underwater sites. The success of this stabilization depends largely on the knowledge of the conditions prevailing in a particular area and the selection of the appropriate techniques.[194] As we have seen, in the Mediterranean Sea the main cause of degradation of underwater archaeological sites are natural and human factors.

Sea currents can remove the protective layer of sediment and leave the archaeological material unprotected and exposed to negative influences of the environment. This may be especially dangerous at those underwater sites containing wooden findings that can remain completely uncovered and unprotected from woodborers.

In addition, many archaeological sites contain metal archeological finds. In case where anchors, cannons and other iron objects lie on the seabed without the physical protection of marine sediments, corrosion will damage the whole structure of these objects. Erosion and disturbance of underwater sites caused by human impact is also a very important factor. There is a common example of the commercial application works on the seabed, but also sport divers during visits to an archaeological site, that could disturb and further destabilize the site. These negative impacts may lead to loss of archaeological material in a relatively short period of just a few years or decades rather than centuries or millennia.[195]

[194] Oxley, I. 1998b, 'The *in-situ* preservation of underwater sites', *Preserving archaeological remains in situ*, eds M. Corfield, P. Hinton, T. Nixon & M. Pollard, Museum of London Archaeological Service and University of Bradford, London, pp. 159-173.

[195] Gregory., Manders, M., Richards, V., The in situ preservation of archaeological sites underwater: an evolution of same techniques, in *Heritage Microbiology and Science: Microbes, Monuments and Maritime Materials,* ed. May,E., Jones, M., Mitchell ,J., (2008), pp. 179-203

In-situ stabilization involves a series of actions that can create physical protection of archaeological sites, which is similar to the natural protection thus preventing the site being damaged by natural and human activities.[196]

6.1.1 REBURIAL AND RE-COVERING METHODS

There are several major techniques for the protection of a shipwreck by covering the site. The basic idea of this method is to ensure the physical protection of the site, similar to that created in natural conditions. In addition, this natural protection, at the same time, prevents penetration of oxygen, which will result in the creation of anaerobic environment that is not conducive to the development of organisms that can cause damage to the site. Re-covering the shipwreck sites can be carried out using sand that was excavated during archaeological excavations or by placing different forms of physical protection which fixes marine sediments. The most common method used for the physical protection of shipwreck sites is the use of sand bags or geotextiles, while for fixing marine sediments artificial sea grass or debris netting are used.[197] Each of these techniques has its advantages and disadvantages In order to achieve the maximum effect of these methods for in-situ conservation; it is possible to apply more than one method at a time.

Reburial method in order to protect a shipwreck site is very often the first method that can be applied, and over time, it has become standard practice.

While some may not consider it in situ preservation, this method does provide very good stability, physical protection of exposed timber from aerobic biological deterioration and offers a possibility to safeguard the

[196] Staniforth, M., In situ Stabilization: The Williams Salthouse Case Study, in *Underwater Cultural Heritage at Risk: Managing Natural and Human Impacts, Heritage at Risk Special Edition,* München, (2006), pp. 52 - 54.

[197] Oxley, I. (1998b). The in-situ preservation of underwater sites. In M. Corfield, P. Hinton, T. Nixon, & M. Pollard, *Preserving archaeological remains in situ,* pp. 100-104.

shipwreck site from unscrupulous divers. Also, it is cost efficient and requires little else in terms of materials.[198]

To be fully effective, this method of protection requires some analysis and planning related to the type of sediment that will be used. In the case when very fine sand to cover and protect the shipwreck site is used, there is a risk that the protective layer will be taken away due to the effects of sea currents. On the other hand, heavy sediments, such as gravel or large stones are much more stable, but can potentially damage wooden archaeological material. A compromise solution to this problem could be the application of this method with other methods that can provide stability and immobility of marine sediments, which will be described in greater detail in the next chapter. In addition to all the advantages of this method previously mentioned, it is important to note that the removal of the protective layer is as easy as its setting. In other words, the reburial method is an excellent solution for the protection and conservation during the period between the two seasons of archaeological excavations and surveys or during monitoring period of a shipwreck site.

[198] Gesner, P. (1993), Managing Pandora`s box - the 1993 Pandora expedition, *Bulletin of the Australian Institute for Maritime Archaeology, vol. 17, no. 2*, pp. 7-10.

6.1.1.1. SAND BAGS

The use of sandbags is a very popular method of covering and protecting terrestrial and underwater sites, because it is a very effective method of protection. Due to their weight, sand bags remain motionless at the bottom, ensuring immobility of the archaeological material, and safeguarding shipwreck site against erosion. That is why this method can be used on different types of underwater terrain. It is particularly effective for shipwreck sites where currents threaten to remove the archaeological material completely. In addition, sandbags have the added advantage of acting as supportive structures for features and artefacts on site, such as hull structures (Picture 6.1)

The downside of this method is that sandbags do not provide sufficient hermetic closure of the site, in other words, they are not able to provide the anaerobic environment and consequently protect the site from biological factors. This problem can be solved by previous setting geotextiles, and then finally a layer of sand. The advantage of this method is has that these sandbags subsequently can be easily removed in case of archaeological research.[199]

[199] Martin, C.J.M. 1995, 'The Cromwellian shipwreck off Duart Point, Mull: an interim report', *International Journal of Nautical Archaeology,* vol. 24, no. 1, pp.15-32.

Picture 6.1 Physical protection of underwater archaeological sites with sandbags

In addition to all the advantages it offers, sandbag method is considered to be a very economical method of stabilizing and preserving shipwreck sites. However, this method is mainly used as a temporary measure of protection. Prior to the application of this method of protection, it is very important to pay attention to a few details in order to provide its higher efficacy.

It is important to note that in order to have a longer duration of sandbags, it is necessary to choose synthetic materials that are more resistant in contrast to the natural materials that can be decomposed in a very short period of time in underwater environment. Another very important detail for this method is to use only fine granulation sand, without the presence of organic content in order to avoid the presence of microorganisms that could potentially lead to degradation of archaeological materials.[200]

[200] Gregory, D., & Manders, M. In, Decay and protection of archaeological wooden shipwrecks, (ed) C. Bjordal, D. Gregory, *WreckProtect* , Information Press, Oxford (2011), pp. 111-121.

6.1.1.2. GEOTEXTILE

Geotextile is a synthetic material used in coastal areas to prevent erosion. (Picture 6.2) This material has found wide application in archeology for the conservation of terrestrial and underwater archaeological locations. This method, though very cheap and simple, gives very good results in the protection of archaeological resources. The great advantage of this method is that it offers the possibility for the conservation of a very large area. Geotextile is very easy to set up on the seabed and easy to remove in case of periodic monitoring of locations or seasonal archaeological researches.

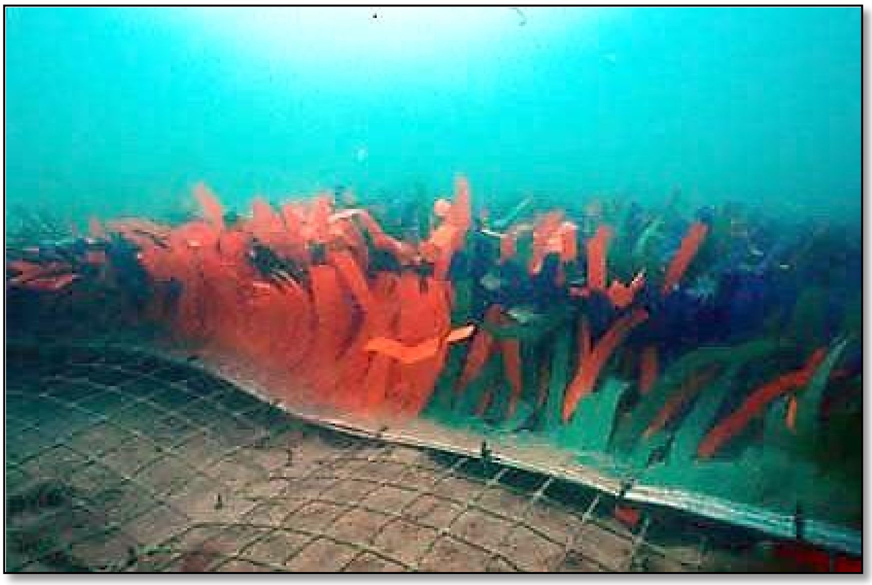
This material is an excellent protection against colonization of T.navalis. However, due to its porosity, this material does not provide sufficient protection against microorganisms. For this reason, it is necessary after the installation of geotextile on the seabed, to fix it using a bag of sand and a thick layer of sand.

Picture 6.2 Placing geotextile over the underwater archaeological shipwreck sites

6.1.1.3. ARTIFICIAL SEA GRASS

All the above-mentioned methods can be used as protection of shipwreck sites against physical and biological impacts. However, these sites can also be threatened by sediment transport. There are several methods that could be used in which take advantage of sediment transport. The principle of this method is that if there is a sediment transport in the waters around the site it can be trapped and held in position in order to cover the site.

One of more effective methods available to archaeologists is to set artificial grass on the seabed in order to protect shipwreck locations against erosion and transportation of sediments. (Picture 6.3) This is a good and reliable technique which has been proven to protect the pipelines and cables that are placed on the bottom of the sea and ocean. The plastic fronds of the artificial sea grass trap sediment particles in the water column as water passes through them. Due to friction, the water is slowed down causing the sediment particles to fall out of the water column resulting in an artificial seabed/mound.[201]



Picture 6.3 Artificial sea grass mat in-situ; (Richards, 2012 page 175.)

[201] Richards, V., McKinnon, J., In Situ Conservation of Cultural Heritage, *Public, Professionals and Preservation,* Flinders University Program in Maritime Archaeology, (2009), pp.1-77.

This method has been demonstrated to be very useful on sites with sandy bottoms and strong currents and severe erosion. The use of artificial grass provides fixing sandy and muddy sediments and does not allow its transportation. This ensures a constant protection of archaeological materials.[202]

[202] Richards, V., In Situ Preservation and Monitoring of the James Matthews Shipwreck Site, *Maney Publishing's Online Platform, Volume 14 Issue 1/4* (November 2012), pp. 169-181

6.2. PERMANENT PROTECTION

Looting of shipwreck sites is a very big problem and one of the biggest threats that lead to devastation and destruction of underwater cultural heritage in the Mediterranean Sea. The development of diving equipment enables a growing number of recreational divers to dive safely in ever-increasing depths. Great cultural and historical heritage of the Mediterranean Sea, which was hidden for a long time in the depths of the sea and inaccessible to people, is now available to a large number of sport divers. Very often, due to curiosity, but primarily in a deliberate desire to appropriate the objects of cultural value unlawfully, the divers take valuable archaeological material. In this way, they have devastated or destroyed many shipwrecks sites. Unfortunately, previous experience leads to the conclusion that it is impossible to protect these sites from looting, despite all attempts to protect them legally and with constant surveillance. All efforts to preserve these sites gave negative results, and after a certain period, most of them have been devastated.[203] This alarming situation requires radical measures to protect the cultural heritage. The only logical solution, was to set a metal grids and the cages in an attempt to physically protect underwater sites physically from looting and further destruction.

6.2.1. PROTECTIVE METAL NETTING

Placing protective metal netting in order to protect the underwater sites is a relatively simple and inexpensive method. It is suitable for sites that are at greater depths, but also for those in the shallower areas, and even for those who are on the beaches. The problem with this kind of protection is that since this protection is relatively easy to remove, so that potential looters of

[203] Jurasic, M., La protezione fisica dei siti archeologici sommersi del fondale marino nell'Adriatico Croato, in *Archeologia subacquea in Croazia*, in cura Irena Radic Rossi, (2006), pp. 147-156.

archaeological sites can remove the barrier without much difficulty and the devastated site. For this reason, the practice has shown that the protective netting must be secure or riveted to the bottom of the sea, with large nail, or should be placed over heavy objects. In the case where a long term protection of a shipwreck site from looting, physical, and biological negative influences, is necessary, it is possible to set up over the metal mesh, geotextile and a layer of sandbags and sand. In this manner it is possible to ensure the long-term physical protection as well as anaerobic environment that will prevent the presence of wood boring organisms.

6.2.2. PROTECTIVE METAL CAGES

A big step forward in terms of methodology, is the positioning and fixing of metal cages over an underwater archeological site. Unlike metal netting, cages cover much larger area. In their production, metal was used that is resistant to corrosion as their construction makes a lot tougher and more resistant and thus provides a much greater and longer-lasting protection of the site. In addition, their role is to protect the site but also to allow for periodic visits, monitoring, and even archaeological works.[204]

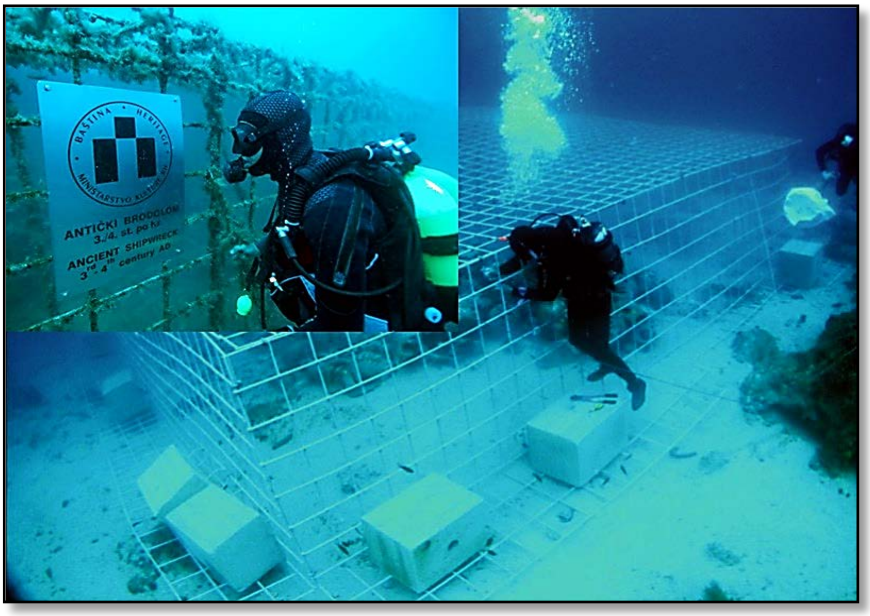
Setting up this kind of physical protection would allow a visit to sport divers who might see an underwater archeological site in a natural setting. This new approach was made possible with the new legal rules and regulations, which allows to local sport diving clubs to obtain special permits and concessions for the operation and maintenance of the protective cage. The obligation of the diving clubs is to carry out periodic monitoring, maintenance, and cleaning of the protective cages.

[204] Neguerela, I., 2000. Managing the maritime heritage: the National Maritime Archaeological Museum and National Centre for Underwater Research,Cartagena, Spain. *International Journal of Nautical Archaeology 29.2:* pp.179-198.

This self-sustainable approach is of the general benefit of the wider community and not just the diving club.[205]

Application of protective cages on archaeological sites is becoming and more a common practice in the area of the Mediterranean Sea especially in the areas where archaeological sites were looted in the past and where treasure hunting and collecting souvenirs has a long tradition. Croatian coast has always been known for its numerous archaeological sites that were completely devastated. This is why physical protection of underwater sites has become a normal practice, especially in undamaged sites that were discovered in the last few years. (Picture 6.4)

After a period of several decades, from the first set of protection, this practice has shown very good results in the protection of archaeological shipwreck sites.[206]



Picture 6.4 Protective cage set up over the archaeological sites Vlaska Mala, on the island Pag in 2004. (photo Moskovic, photo documentation HRZ Zagreb)

[205] MESIĆ, J. - A Resource for Sustainable Developement: the case of Croatia, Museum International, *Underwater cultural Heritage 240, UNESCO/Blackwell Publishing,* (2008), pp.91 - 99.

[206] Zmaic, V. - The Protection of Roman Shipwrecks „in situ“. Underwater Museums, in: Miholjek, I., Bekic, L.,. (ed.) *Exploring Underwater Heritage in Croatia*, Zadar, (2009), pp.18 - 19.

6.3. SITE SUPERVISION AND MONITORING

Monitoring and supervision of underwater archaeological sites is extremely important for the process of conservation of underwater cultural heritage. There are many threats to archeological sites and they come from the influence of man and biological factors. There are also several very successful methods that can be used in order to protect these sites. However, these methods of protection cannot guarantee success in all conditions and for this reason they require constant supervision and monitoring.

It is important to note that a shipwreck site in a state of strong dynamic equilibrium with its natural surroundings where possible permanent changes due to frequent natural factors. Potential changes, even the smallest ones, can initiate a range of irreversible processes that could lead to the degradation of the site. For this reason, it is important to periodically monitor and make certain adjustments to ensure the continued stability of the site. Practically, monitoring involves periodic inspection sheet shipwreck and its conservation of the archaeological site, after applying some of the methods of in situ conservation.

The process of in-situ stabilization and conservation is very complex and time-consuming process that depends on a lot of factors and parameters. The success of the whole process depends on the knowledge of the all key factors and their changes over time. Any change in the site could be used for comparison with the situation as it was in the moment of conservation.

There are many parameters that can be monitored at one site, and all these parameters may change over time for a number of reasons. Each of the possible changes related to any of the monitored parameters, may suggest the specific changes that may affect the conservation of the site. At the same time, these changes may suggest that most of the potential danger threatens site and take measures to prevent degradation.

The most important parameters that must be monitored regarding the environmental conditions are the location where an archeological site is, and the situation in which the archaeological remains are on the site.

6.3.1. MONITORING THE PHYSICAL CHEMICAL CHARACTERISTICS OF THE ENVIRONMENT

When it comes to environmental conditions, they primarily refer to the physical and chemical characteristics of seawater and features relating to marine sediments. All data related to these important parameters can be collected directly at the site or any valid information can be obtained from an oceanographic institute. It is desirable to, carry out the tests in the field, in order to obtain the relevant information before the process of protection and conservation starts.

It is important to note that the constant monitoring and visual inspection of marine sediments, is a very important part of the process. Visual monitoring of marine sediments involves teams of divers and specialized teams who will use the remote method (ROV, Multi Beam, Side scan sonar), supervise, and control all potential changes.

6.3.2. THE PRESENCE OF WOOD BORING ORGANISMS AND THE LEVEL OF DAMAGE TO WOODEN STRUCTURES

The problem with wood boring organisms is the biggest problem for the conservation of archaeological shipwreck sites in the Mediterranean. Their conservation depends largely on the effective protection from these organisms. Before beginning, the process of conservation it is very important to determine the presence of wood boring organisms and the degree of damage of wooden structures. During the monitoring of the shipwreck, it will be possible to monitor their presence and development but also the degradation effect that they have on wood. However, it is very difficult to determine the extent of damage to the wooden material that is colonized and degraded by T.navalis, because degradation process takes place in the interior of wood and the entire process and the effect of degradation are invisible. For this reason, the best method in order to follow the development and activity of these organisms is the appointment of sacrificial piece of wood, approximately to the site. Based on the results collected during the periodic analysis of these samples can be determined the presence and type of wood boring organisms can be determined, but also the rate of decomposition and degradation of wood materials.

There is also a range of parameters that can be monitored which make part of an archaeological site. These parameters depend on the type of site, as well as the specific characteristics of the environment in which it is located. Careful and long-term monitoring of the conditions at the site, as well as factors that affect the state of the archaeological findings, can be of great help to determine the appropriate strategies and methods in order to protect the site. Various environmental factors affect different types of archaeological materials-metal, ceramic, stone, and wood in a special way and each of these methods requires a specific approach to monitoring these parameters, but also the specific treatment of different archaeological materials.

It is important to note several important projects that are aimed at research and study of the degradation process and degradation of archaeological material in-situ monitoring of these processes, as well as a few basic methods that can be applied in order to best protect archaeological sites.

Project RAAR that included special investigation of all types of materials that can be found at an archaeological site. Also very important is MoSS Project (Monitoring, Safeguarding and Visualizing North-European Shipwreck Sites), whose main goal was to research and better understand of the degradation process and the protection of archaeological sites. Similarly project is BACPOLES (Preserving cultural heritage by preventing bacterial decay of wood in foundation piles and archaeological sites), whose main objective was to survey the archaeological wooden finds by the action of bacteria and fungi.

6.4 OUTCOME OF IN SITU CONSERVATION METHOD

Excavation and raising a shipwreck from the seabed is a shipwreck is very complicated, time-consuming and expensive process. It can be considered to be very unrealistic, even impossible, to excavate, and raise from the bottom all the shipwrecks that have been found in the Mediterranean Sea. For this reason, in situ conservation and physical protection has become an alternative to excavation, as a long-term solution for the conservation of the shipwreck sites. An important advantage of this method, compared to the excavations, is the possibility of returning to the site and continuing with the following research or carrying out monitoring for a certain period of time, without excessive and unnecessary jeopardizing of the archaeological sites, which can cause irreversible loss of archaeological context of the site.

All above-mentioned methods for in-situ stabilization and physical protection of shipwreck sites have proven to be extremely effective in the environment of the Mediterranean Sea. The method is very reliable, easy to install, has no negative impact on the seabed and the environment, and is very inexpensive. Although, this method involves periodic control and monitoring, that is not a negative aspect but a big advantage because there is always a possibility of temporary removal of the protection.

There are several examples of shipwreck sites in the Mediterranean Sea that were protected using methods of in-situ stabilization and conservation. A good example is the Roman shipwreck Spargi (Sardinia, Italy), which has been protected and conserved by covering it with a thick layer of sand and stones, after several attempts of looting.[207]

[207] E. Riccardi, *Tecniche di lavoro subacqueo per l'archeologia.* Mare ed Ipogei, Savona, (1998), pp. 55-57.

Another good example is an effectively protected and preserved post-Byzantine shipwreck in Zakynthos using the geotextile and a thick layer of sand.[208]

This method of conservation of shipwrecks is also suitable for the conservation of underwater archaeological and architectural structures. Effective application of geotextiles and sand bags has been applied in conservation of underwater archaeological sites Torre Astura and Baia (Napoli, Italy), for the conservation of floors and mosaics on the site.[209] In some cases, shipwrecks that have been found in shallow water or on beaches can also be conserved by using these methods. An example is the wreck from the Roman period, which is located on the site of Torre Santa Sabina (Brindisi, Italy). The boat is placed in a location that is close to the tourist center, and for that reason it was continually robbed before it hes been covered and protected by a layer of geotextile sandbags and cement blocks.[210]

[208] A. Pournou, A. Jones, A. Mark, S. T. Moss, Monitoring the environment of the Zakinthos wreck site, in Art 99: 6th International conference on non-destructive testing and microanalysis for the diagnostics and conservation of the cultural and environmental heritage, Rome, May 17-20, 1999 / Istituto Centrale per il Restauro, Rome, Italy. Associazione italiana prove non-distruttive (AIPnD), Italy, (1999), pp. 2001-2008;

[209] Petriaggi, R., Davidde,B., Restaurare sott'acqua: cinque anni di sperimentazione del NIAS-ICR. *BollettinoICR, vol. 14,* (2007). pp. 127-141.

[210].Davidde, B, Methods and Strategies for the Conservation and Museum display in-situ of underwater Cultural Heritage, *Archeologia marittima Mediterranea, vol.1* (2004), pp. 136-150

7. CONCLUSION

The area of the Mediterranean Sea is very rich in cultural, historic, and archaeological heritage. On its shores and islands great ancient civilization were created, they grew and disappeared and the history of the Mediterranean is a kind of interaction between different cultures, religions and peoples who inhabited this region. We can rightfully claim that these ancient civilizations gave a great contribution to creating a society in which we live now.

A large part of that archaeological and historic cultural heritage consists of shipwrecks that are a kind of evidence and testimony to the development of human societies, their cultures, economies, and technologies. However, despite their great cultural value, these shipwrecks are highly endangered. There is a constant and increasing risk of their deterioration and destruction caused by negligence, intentional or unintentional actions of man, but also by poorly planned interventions aimed at their preservation and rescue.

Modern society is constantly and rapidly developing. As we now build and construct what will, one day, become just remnants of our civilization, at the same time, we consciously or unconsciously destroy the material remains and testimonies of human life from the past that have been preserved until today.

In the case of destruction of shipwreck sites, or compromising their authenticity, it will be impossible to restore them to their original state and they will be lost and will forever remain inaccessible to future generations. The only way to ensure the survival of a shipwreck is by designing innovative ways of protection and conservation that will prevent their further degradation and destruction. For this reason, the primary task of archaeologists, conservators, and historians is to protect shipwreck sites and other underwater cultural and historical heritage.

Simultaneously with this process of protection, it is important to educate and raise awareness of the population for the purpose of better understanding of the importance and value of underwater archaeological shipwreck sites, which is also one of the main guidelines listed in the UNESCO Convention of 2001 related to the Protection of Underwater Cultural Heritage.

Paradoxically, despite the growing efforts of the international community to preserve shipwreck sites and to raise awareness of their importance and value for the global community, there is, at the same time, an increasing level of their destruction. Notwithstanding all international legal provisions stipulated in the UNESCO Charter, as well as the laws in place in developed countries worldwide, shipwreck sites are, unfortunately, day after day more jeopardised mainly due to human activities. Total subordination to making profit, monopoly and political power, leaves governments of those countries completely blinded and they, despite knowledge of the vulnerability of the natural environment and the underwater cultural heritage, do not take any action, or take insufficient ones to ensure their protection. In this way, valuable testimony and evidence of human activities from the past as a unique and non-renewable source of information are permanently damaged, or destroyed.

The deterioration of materials and objects is a natural process and it is very important to understand that it is impossible to permanently conserve a shipwreck site. In the best case, over time, all these sites will eventually disappear due to the effects of physical and biological factors, which exist at the bottom of the sea. However, by taking timely action and using appropriate methods for the protection of shipwreck sites, they can be preserved and protected from adverse environmental impacts and their existence can be significantly extended.

The main objective of this thesis is to carry out a complete analysis of all the key factors that positively or negatively affect the conservation of archaeological material in order to find the best possible way for the implementation of in-situ conservation of shipwrecks in the Mediterranean Sea.

It must be kept in mind that in-situ conservation in the Mediterranean Sea is a very complicated process that requires a multidisciplinary approach and analysis of the most important parameters and factors. For this reason it was necessary to break down the entire problem into its basic components (definition, value and importance of the process of formation of shipwreck sites, the greatest threats that jeopardise it) in order to better understand and find a more efficient method for protection and in-situ conservation of shipwreck sites. In addition, this complex analysis had to be supported from the theoretical point of view, as well as by the latest researches conducted in the area of the Mediterranean Sea. Also, it was necessary to provide an argumentative reflection and comparative analysis of the methods and results of studies that have been applied in other areas. For this reason, the importance of projects that were carried out in the Baltic Sea in recent decades must be noted. Discoveries and conclusions from these projects have made a great contribution in the field of in-situ conservation and gained experience and knowledge have enabled the use of this method even in conditions that are significantly different from the Baltic, like, for example, in the area of the Mediterranean Sea.

As it has been repeatedly emphasized in this thesis, the area of the Mediterranean Sea, due to its specific characteristics, does not provide favourable conditions for good conservation of archaeological materials. The main problems associated with in-situ conservation in the Mediterranean Sea are related to natural environmental conditions, more precisely, physical and biological impacts, but also the human factors that have the greatest influence on the degradation of a shipwreck. For this reason, a large part of the thesis is devoted to the analysis of these factors and the potential danger that they pose to a shipwreck site. It is highly important to understand how significant their impact on the degradation of archaeological shipwreck sites is, and that the future protection methods and in-situ conservation will mostly depend on them.

As a final conclusion, after all the analysis and the said various methods of in-situ conservation, we can say that this in-situ method has proved to be extremely effective in protecting the shipwreck site because it offers some very important advantages compared to other classical archaeological methods.

Firstly, in-situ conservation is a non-invasive method that aims at ensuring the physical protection of sites from negative environmental influences, and thus completely slowing down the degradation of archaeological materials. Another very important aspect of this method is that in-situ conservation allows the preservation of the integrity of the shipwreck site, which means that this method does not envisage the movement of archaeological material from its original place. This is very important because, due to displacement and dislocation, archaeological material loses its original context, which means the loss of valuable information. To avoid this, it is necessary to carry out a comprehensive archaeological documentation. Unfortunately, preparation of the complete documentation is in most cases a complex, time consuming, and expensive process. Very often, when it is necessary to implement emergency protective archaeological work at the site, there is no enough time for the production of the complete documentation. Another big advantage of this method is that conserved and fully integrated shipwreck site remains available to future generations and for future scientific researches.

Finally, in-situ conservation is very cheap and also very effective method of protection. In recent decades, a lot of shipwreck sites were discovered in the Mediterranean Sea. Unfortunately, in many cases a lack of money for archaeological researches and conservation, as well as the lack of adequate space for storing the material, prevent the archaeological excavations on the discovered shipwrecks. Often, the provision of sufficient financial funds for archaeological researches is a big problem.

In some cases, several months or even years pass from the discovery of shipwreck to the start of the first archaeological works. Long delays of archaeological work due to lack of funds or because of belated intervention, can cause great damage to the shipwreck site due to the impact of natural or human factors.

All these mentioned problems present a major challenge for modern archaeology and in-situ conservation is the only acceptable and logical solution for the long-term protection and conservation of shipwrecks in the Mediterranean Sea. Having in mind that it provides a lot of advantages and benefits, in-situ conservation has become a very important and very often applied method for protection and conservation of many underwater archaeological sites. According to the latest UNESCO international standards In-situ conservation is considered as the first option when planning a temporary or long-term protection of a shipwreck site.

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