UNIVERSITY OF GOTHENBURG

DEPARTMENT OF CONSERVATION

THE LONG-TERM EFFECTS OF UNDERWATER ARCHAEOLOGICAL PARKS ON THE PRESERVATION OF UNDERWATER CULTURAL HERITAGE

An Overview

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ABSTRACT

The 2001 UNESCO Convention on the Protection of Underwater Cultural Heritage (UCH) indicates preservation *in situ* as a first option and encourages public access unless it is incompatible with protection and management. Protection methods address natural factors that include environmental conditions and microorganisms, and human impact, direct or indirect. Public access through the operation of diving parks might be incompatible with the material preservation of UCH because of exposure to these threats. Literature research from conservation's standpoint, indicates the following remarks to be taken into consideration in decision-making processes: a) exposure of wood and marble in the sea column is highly probable to lead to their deterioration, therefore, their reburial or covering should be implemented; b) informational preservation, physical or digital, is a valuable alternative way to communicate the content of a site, but does not constitute a conservation method; c) legislation and education are powerful tools for eliminating the human threat to UCH. This thesis concludes that the long-term effects of diving parks on the preservation of UCH can be beneficial as long as they operate according to these remarks and do not allow unsupervised public access and uncontrolled site conditions.

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1. INTRODUCTION

1.1 Background

“How can you call this planet earth, when it is quite clearly water?’’ This question appears in the first pages of the information brochure for the 2001 UNESCO Convention on the Protection of Underwater Cultural Heritage and aims to draw our attention below the water surface, where remains of humankind’s history lie beyond our sight and, quite often, beyond our reach. The most recognizable figure of these remains, is probably the sunken ship, also called the *archetype* by Wikajnder (2007), but Underwater Cultural Heritage (UCH) includes much more:

> All traces of human existence having a cultural, historical or archaeological character which have been partially or totally underwater, periodically or continuously, for at least 100 years, such as:
>
> (a)i. sites, structures, buildings, artefacts, and human remains, together with their archaeological and natural context;
>
> (a)ii. vessels, aircraft, other vehicles or any part thereof, their cargo or other contents, together with their archaeological and natural context; and
>
> (a)iii. Objects of prehistoric character.

Objects that are not regarded as UCH are:

> (b) Pipelines and cables placed on the seabed
>
> (c) Installations other than pipelines and cables, placed on the seabed and still in use. (UNESCO, 2001 p.2)

Regarding their protection, the 2001 Convention established the principles that should dictate the activities related to UCH. They concern the obligation to preserve UCH, the preservation *in situ* as a preferred option, the condemnation of commercial exploitation, the training and information sharing and the non-regulation of the ownership of heritage. The present thesis will focus upon the following two Annex Rules:

> Rule 1. *In Situ* preservation as first option (in its original location on the seafloor). The recovery of objects however may be authorized for the purpose of making a significant contribution to the protection or knowledge of UCH.
>
> Rule 7. Public access to *in situ* underwater cultural heritage shall be promoted, except where such access is incompatible with protection and management. (UNESCO, 2001)

1.2 Purpose and Research Questions

The aim of this thesis, is to examine the occasions in which public access is incompatible with the protection of UCH. In other words, it can be formed as the following research question:

How can diving parks in marine archaeological areas* affect the preservation of UCH in the long-term?

The sub-questions that will lead to this answer, will focus on:

- *What are the main threats of UCH?*
- *What are the protection strategies for UCH and how do they relate with public access?*
- *Are there alternative ways to preserve and exhibit UCH?*

1.3 Delimitations & Definitions

Cultural heritage terms have often been contested regarding their interpretation, and ''underwater'' is not an exception. This aforementioned definition has been subject to some criticism and Forrest (2002) discusses the points that are disputable (such as the 100 year limit), but expanding on this territory is beyond the scope of this paper, and so are the intangible qualities that are connected to tangible underwater heritage sites.

Moreover, in this thesis, the term UCH will address only objects from marine environments and not from other types of waterlogged sites, e.g. lakes, rivers or waterlogged environments on land. In particular, the objects and sites that will be investigated will be the ones that are most representative. Classified by material, these are: wood (historic shipwrecks), iron (modern historic shipwrecks) and stone material (sunken cities and their monuments) (Davidde, 2004).

Definitions

Scott-Ireton (2005) observes that the establishment of underwater archaeological sites is quite recent and there is no concrete museological theory addressing this. They can be compared in parallel to ''open air museums'' or can be called ''museums in the sea'', but official terms vary. Therefore, it is essential to clarify some common misconceptions and define the terms that will be used for the purpose of this thesis.

The first distinction to be made is between Marine Protected Areas (MPA) (known also as Marine Parks) and Diving Parks. The first category refers to marine areas designated for the protection and sustainable management of fishing resources and marine biodiversity. The second category, Diving Parks, are small scale marine areas suitable

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*Equals to public access *in situ*, see section 1.3

for recreational diving in terms of location and underwater formation, marked with buoys, closed for any intervention or activity other than recreational diving, seabed observation and scientific research. They are mainly closed for any form of fishing too. Moreover, they are sustainable and financially viable through the revenues from the tickets of the visitors and also independent from the existence or not of wider national Marine Protected Areas in their region (Markatos and Koutsis, 2008).

When a marine archaeological/historical area is open to the public for recreational reasons and can be visited by divers or visitors on glass-bottom boats –thus, there is a diving park integrated in a marine archaeological area-, it is usually called an Underwater Archaeological Park. If such areas, apart from the historic site, combine points of geological/morphological interest, they are called Underwater Eco-Archaeological or Nature-Archaeological Parks and Reserves. When they are not open to the public, they are Underwater Archaeological Reserves, which do not have the possibility to operate as Diving Parks, but are open for study and investigation. Finally, a marine site is called Untouched Underwater Archaeological Reserve when any human activity is felt to be harmful for both the natural and archaeological resources found (Davidde, 2002).

1.4 Methodology

The research questions will be investigated as a literature study using the available and accessible literature in the English language. It will be based on international scientific articles including also both interdisciplinary research projects and case studies. The information available will be discussed from the conservator's standpoint and ethics. It will also present the current and future tendencies that constitute conservation of cultural heritage a dynamic and interdisciplinary field.

There is an important amount of research carried out in the field of *in situ* preservation of wooden shipwrecks and several case studies about the operation of diving parks. However, the literature regarding the long term effects of diving parks on the preservation of the materials that constitute UCH, specifically from a conservator's standpoint, is still limited. This thesis' contribution is a first step towards this direction. It attempts a holistic approach to the knowledge around the subject, and aspires to shed light into the advantages and disadvantages of the preservation *in situ* of UCH and the occasions when public access is compromised with such measures.

1.5 Disposition

The first chapter, introduces the notion of underwater cultural heritage and the official principles regarding its preservation. It sets the ground for the scope under which these preservation aspects will be examined and the objectives of this thesis.

The second chapter presents the most common degradation factors of underwater cultural heritage. They are classified as natural and human and discussed by their effects on the three different materials.

The third chapter discusses the measures that underwater archaeological parks employ for the protection of UCH against natural and human factors.

The forth chapter examines informational preservation as an alternative way of protection and exhibition of UCH.

The fifth chapter attempts an assessment of the methods and strategies and the way forward in preservation of UCH.

The sixth chapter summarizes the conclusions obtained from this overview.

2. THREATS OF UNDERWATER CULTURAL HERITAGE

The ocean floor is divided in different zones (figure 1), from which the pelagic and benthic are the ones that determine the degradation of materials in marine archaeological areas. The pelagic zone is the most dangerous and specifically parameters such as temperature, salinity, oxygen, light and pH affect the presence and distribution of microflora and microfauna that can become harmful for the historic materials. Additionally, the symbiosis and competition between species is indicated by biodiversity, which at the same time, can be disturbed by pollution. Finally, local conditions and hydrographic changes due to river estuaries, rainfalls, and tides play an important role in the preservation condition of a submerged site or object (Pearson, 1987).

Concerning the benthic zone, it consists of aerobic and anaerobic sediments. The two most important features are grain size and grain distribution because they determine, among others, the mobility of the particles, the distribution of microfauna and the water content. Moreover, microenvironments such as interfaces between the water, the object and the sediment affect degradation, as well as smaller areas within the same microenvironment such as contact of wood with metal. (Pearson, 1987).

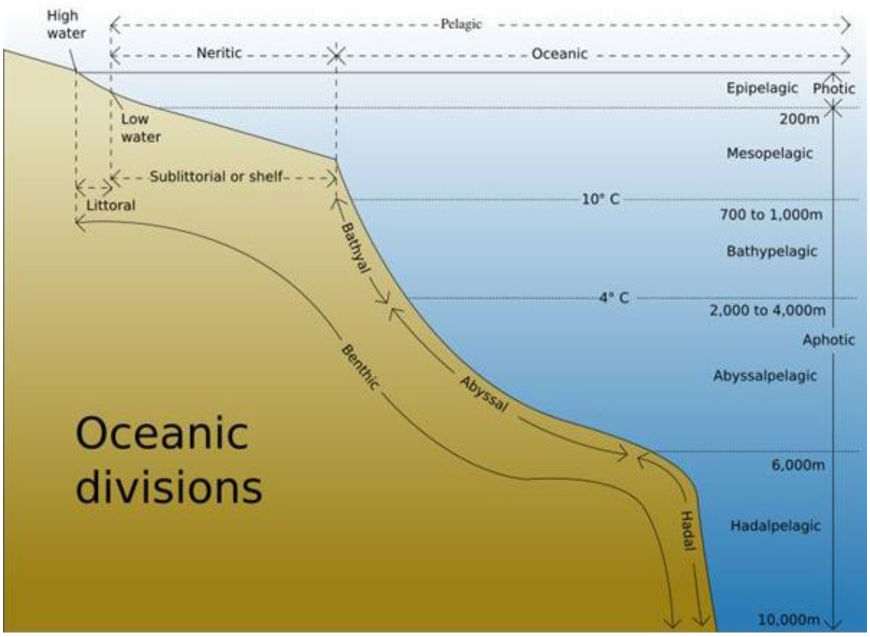

Figure 1: Topography of the ocean floor. (Aggeliki K., 2013)

The threats of UCH are originated by two kinds of factors: 1) Natural factors, which include the aforementioned water and sediment characteristics and the marine organisms (biofouling communities, wood borers and microorganisms) that settle on the sites and objects. 2) Human factors, which include indirect anthropic activity (e.g development works, mooring constructions, fishing and anchoring) and direct (recreational diving). These threats will be described in relation to the most representative materials of UCH: wood, stone and iron.

2.1 Natural factors

2.1.1 Wood

Wood is an organic material, composed mainly of the polymers cellulose hemicellulose, and lignin, whose proportion varies among species and category of trees. (Haygreen and Bowyer, 1989). These polymers constitute the wood cell walls. They are aligned in microfibrils in a spiral orientation, following the direction of the 3 layers in the secondary wall (figure 2). This provides strength to the fiber cells, and to the living tree as well (Haygreen and Bowyer, 1989)

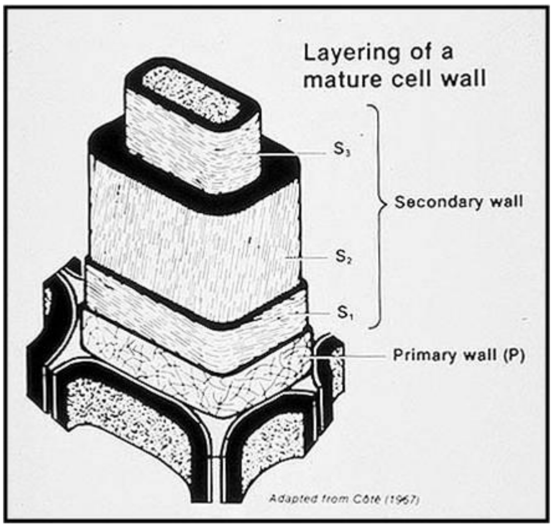

Figure 2: Layering of a mature cell wall. (Roberta Farrell, n.d.)

When submerged in the sea, wood becomes a nutrition source for marine borers, which are divided into mollusks and crustaceans. The most common and widely distributed around the seas, is *Teredo sp*, known also as shipworm. It belongs to the group of bivalve mollusks and degrades the wood interior. After it settles on wood, it is nourished by the cellulose and hemicellulose inside the wood, by rasping movements that gradually form a small circular burrow. While growing, shipworms release calcareous substances that attach to the walls around it. (Björdal and Appelkvist, 2011). The tunnels only become visible when a piece of wood is broken (Grosso, 2014) (figure 3).

Shipworms live in oxygenated and salty marine waters, and for that reason they are a severe threat for archaeological wood lying exposed upon the seabed, but not for those that are protected in sediment. Moreover, Eriksen et al. (2017) observed a correlation between the extent of the tunnels in the samples and the material density and cellulose content of the wood. Specifically, samples with a low density (<100kg/m^3) and low cellulose content ($\leq$24% weight/ dry weight) were not attacked, whereas better-preserved objects suffered low to severe attacks. However, it was not possible to determine the point where microbial degraded archaeological wood already becomes ''unattractive'' to shipworm.

The family of *pholadidae* also has members that degrade wood, even if not so severely. They do not secrete calcareous layers and they do not have a wormlike body, except for the Xylophaginae (Grosso, 2014). In contrast to the ''cosmopolitan'' *teredo* species, *pholadidae* have small spread around the world and remain one of the species whose effects on wood degradation has been only little investigated (Bastida et al., 2004).

Regarding crustaceans, the most common species belong to the families of *Limnoriidae* ("gribble") and *Sphareomatidae* ("pill bug"). In contrast to shipworms, they affect the surface of the wood, because they have legs that allow them to walk on it, and form small cylindrical channels that gradually honeycomb it (Haygreen and Bowyer, 1989). They need oxygen to survive and for that reason they attack only the surface of the wood and cannot extend deeper into the material. *Limnoria tripunctata* is a temperate-tropical species, is one of commonly reported species of this genus and *L. quadripunctata* is a temperate species that has been found in temperate waters world wide (Pournou et al., 2001)

Apart from marine borers, wood also gets attacked by marine fungi which turn its surface soft. For that reason they are known as *soft rot fungi*. They belong to the group of *Ascomycetes* and *Fungi imperfecti* and degrade wood in aquatic environments where oxygen is limited (Björdal, 2012). They attack the cellulose in the secondary cell wall following the orientation of the microfibrils. As a result, they create cavities with longitudinal helical orientation and conical ends (type 1- most common). Alternatively, their attack can take the form of enzymatic release which erodes the cell wall and gradually the fiber (type 2) (Björdal, 2012).

Figure 3: Degradation in the interior of wood sample caused by Teredo Navalis. (WreckPorotect 2011)

Another kind of micro-organisms that attack wood are bacteria. There are two types. The first ones are called erosion bacteria and degrade all types of archaeological wood found in waterlogged, near anaerobic conditions. They deteriorate the cellulose rich parts in the secondary cell wall, and they do not affect the lignin rich parts found in the middle lamellae (figure 4). This remaining non-degraded part of the wood is possibly the reason that the archaeological wood preserves its form and main structure while wet (Björdal, 2012).

The second type are called tunnelling bacteria. They need comparatively higher oxygen conditions and are found in the surface layers of submerged timbers, often where the soft rot fungi are also located. As their name indicates, they form individual tunnels with characteristic ''wall'' deposits in the wood's cell wall and attack all its polymers. As they divide, they create new ones, building a network of tunnels (Björdal, 2011)

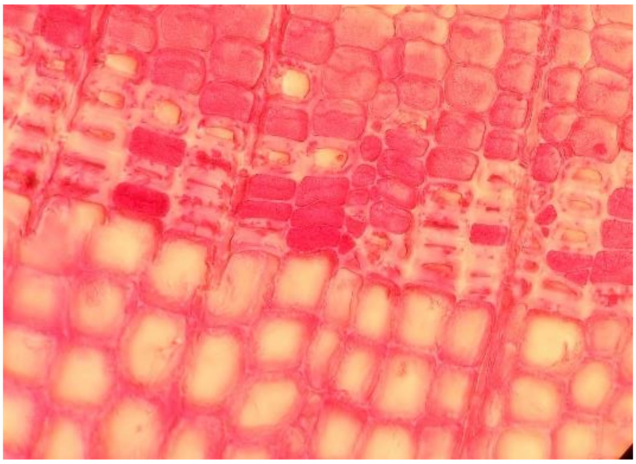

Figure 4: Decay of wood fibers caused by erosion bacteria (red areas) and soft rot fungi (red spots), next to non-degraded wood fibers (white areas). Transverse section of a spruce sample (Image by the author, 2017)

Finally, where wood is exposed in the sea environment, the surrounding conditions can affect the presence and activity of microorganisms and consequently its preservation state. They are interrelated, but also act upon the wood and wood-degrading organisms independently.

The most common parameters that have an impact on degradation of waterlogged wood are water and sediment movement, oxygen, temperature, salinity, pH, redox potential, depositional process, as well as wood species. Water currents can cause physical degradation because of mechanical movement that rolls the remains over rocky or benthic surfaces or mechanical abrasion caused by sediment movement. Oxic environments sustain wood boring organisms and soft rot fungi. Erosion bacteria act in dysoxic conditions and it's the only form of biodegradation in certain sediment layers. Differences are shown between two wood species, but also within different parts of the same wood. In general, gymnosperms, show lower degree of degradation because of the guaiacul lignin they contain which is toxic for the borers. Moreover, heartwood degrades less than the sapwood, probably because of the contained carbohydrates content that act as microbial nutrition (Jordan, 2001). Regarding temperature, the warmer the waters, the higher is the degradation rate of wood, because it accelerates the reproduction and growth of teredinids and limnoriids. (Pournou et al. 2001)

2.1.2 Stone

Stones or rocks are classified as:

- Igneous/ magnetic/ primary rocks and derive from a hot silicate flux. In slow cooling process, it produces rough-grained rocks, such as granite, and after fast cooling near the Earth's surface, finer ones such as basalt.
- Sedimentary or layered that derive from accumulation of rubbles and/or organic material (e.g. shells), such as sandstone, limestone and shale.
- Metamorphic rocks can be initially any of the above and under heat and pressure undergo re-crystallization, rearrangement of the crystal structure of the original rocks. In that way limestone becomes marble, sandstone becomes quartzile and shale becomes slate. Stones are characterized by mineral composition, fabric, texture, structure and color (Pearson, 1987).

Research regarding the biodeterioration mechanisms of stone in underwater environment comes almost exclusively from the Mediterranean and the type examined is marble, which is found usually as remains from trade cargo or building material of sites that submerged due to natural phenomena (Cámara et al., 2017) (figure 5).

Figure 5: Marble statue recovered from the Antikythera shipwreck, showing extended biodeterioration. (K. Xenikakis, 2014)

Biodeterioration of stone is described as the result of two processes:

a) *Biofouling*, which characterizes the "accumulation of micro and macroorganisms on the surface of submerged materials", including their deposits and encrustations of calcareous nature. It is further classified into *microfouling*, caused by bacteria, yeast and diatoms, and *macrofouling*, caused by macroalgae, barnacles, tube worms, bryozoans, mollusks and mussels (Cámara et al., 2017).

b) *Bioerosion*, which characterizes the removal of stone particles through mechanical (bioabrasion) and /or chemical actions (biocorrosion) of micro- and macro-organisms.

(Ricci et al., 2015). It is also divided in *microbioerosion*, caused by cyanobacteria, algae, heterotrophic bacteria, fungi, foraminifera and *macrobioerosion*, caused by clionaid sponges, polychaetes and lithofagine bivalves (Cámara et al., 2017).

The organisms that take part in both kinds of bioerosion, are described by the following terms: e*pilithic,* describes the erosion taking place on the outer surface in the form of microbial patinas and calcareous deposits. The term *euendolithic* describes the creation of cavities or tunnels inwards the rock, with chemical or physical means (calcium pumps, respiratory carbonic acid and/or enzymes). The term *chasmolithic*, describes the action inside stone cracks and microcavities, mostly by microalgae and cyanobacteria (Ricci & Davidde 2012). All kind of species show an upward trend in number, covering and boring patterns along with the immersion period (Casoli et al., 2015).

Finally, the most frequently encountered type of bioerosion is *pitting*. It is caused by euendolithic sponges (*Clionidae*) that have the ability to dissolve stone by acidic emission, extract micro fragments (chips) and abort them through exhaling. (Ricci & Davidde 2012)

Biodeterioration varies in relation to the environmental conditions present in seawater (chemical composition of water and sediments, light, nutrition sources, water movement, depth) and the materials' characteristics mineralogical composition and textural factors (e.g. porosity or crystal distribution).

The most recent experimental investigation on environmental conditions was conducted in the Arqueomonitor Project, Bay of Cádiz, SW Spain, for 18 months. Cámara et al. (2017) describe that two types of marble (Macael and Carrara) were tested in 3 different conditions: (I) exposed in the water column, 1 meter above the bottom, (II) burial and unearthing (semi-burial), positioned in 11m depth resting on the seabed, and (III) permanent burial in 30-40 cm. The results showed several forms of biofouling and bioerosion related to the position of the sample.

Specifically, in environmental condition I, both epilithic and endolithic organisms colonized the sample, mostly barnacles and tube worms but also bryozoans, mollusks and coralline algae. They covered 32-25% of the surface, and bioerosion had the form of micropitting in the first millimeters of each of the marbles. In environmental condition II the same kind of biofouling took place, but in weaker degree. Tube worms and barnacles were also the most common species. Finally**,** environmental condition III showed lower biodegradation with scarce distribution of barnacles and worms. It is evident that the position of the material in the seawater attracts the colonizers due to light and nutrition availability. Micropitting was present in all samples, following the declining degree too. However, they state that Carrara marble was an exception. It proved to be more resistant for at least for 18m, due to its dolomite crystals that act as a barrier against endolithic microorganisms (Cámara et al., 2017).

A similar experiment was conducted in Italy, in the marine protected area of Baiae which is rich in archaeological remains, where 4 calcareous panels were placed 10 cm above the sandy-muddy sea floor for 3, 6, 9 and 12 months. Casoli et al. (2015) state that after 3 months, biological colonization was already covering 90% of the surface, and after 12 months it had expanded to 130%. Only algae decreased over time, as encrusting species and barnacles took over. It consisted of a great diversity of species, which competed for space, with the encrusting species occupying the most. Moreover, the alteration of substratum from the initial colonizers, after 1 year, attracted new organisms, more competitive. Finally, bioerosion was heavy, both in parallel and vertical to the surface, as the boring activity starts from an initial small point and expands to an internal network, away from phototroph epilithics. They conclude that the increasing bioerosion up to 500 μm in the rock, a thick and homogenous layer, is due to the placement of the sample in shallow waters and the material distribution.

Concerning the threat of marine bivalves, Ricci et al. (2015) mention that their growth depends on the seawater's conditions, habitat's physical features, nutrient and space availability, and the substratum composition. If the composition is calcareous, its type (limestone, calcitic or dolomite, marble, travertine), its disposition of surfaces, the morphology of the rocky bottom and the depth, affect their development too. For that reason, they are encountered in tropical waters, which are rich in coral reefs, and less in temperate regions.

2.1.3 Iron

Metal corrosion is interrelated with oxygenated seawater and depth, and influenced by water movement and depth, salinity, temperature, oxygen content and metal characteristics (MacLeod and Richards, 2011).

Corrosion of iron is caused by its contact with oxygen. It is described by the reaction $4Fe+2H_2O+3O_2 \rightarrow 4FeO_2(OH)$, where FeO(OH) are the typical rust-red deposits.

This reaction consists of two local reactions happening on the metal surface. An anodic one where electrons flow from the metal and therefore it becomes positively charged, described as: $Fe \rightarrow Fe^{2+} + 2e-$. The other reaction is a cathodic one where oxygen is receiving the electrons and the charge becomes negative and is described as: $O_2+2H_2O+4e^- \rightarrow 4OH^-$ (figure4).

To maintain charge neutrality in the metal both the anodic and cathodic reactions must occur at the same rate. This flow occurs in an electrolytic solution which in this case is the seawater.

Specifically in warm tropical seawaters, ferrous materials become covered by a layer of marine growth/ concretion (consisted mainly be encrusting organisms such as coralline algae and bryozoans). This layer acts partially as a kind of isolation to the metal surface (where the anodic reaction/ oxidation takes place) from the dissolved oxygen in the water (where the cathodic reaction/ oxygen reduction takes place). As a result, chloride ions that trespass the concretion layer, accumulate right upon the metal surface and acidity rises. Usually, formation of ferrous chloride ($FeCl_2$) occurs, which is subsequently hydrolyzed to a mixed iron (II) hydroxyl chlorides:

$2FeCl_2 + 2H_2O \rightarrow [Fe(OH)_2.FeCl_2] + 2H^+ + 2Cl^-$

The combined potential of all the oxidations and reductions happening on the same metal surface is called corrosion potential (Ecorr) (Pearson, 1987). The potential of corroded iron is of mixed voltage due to the combination of oxidation and oxygen reduction that take place.

The corrosion rate stabilizes after long term immersion, at which point metals corrode at a quasi-equilibrium state. Therefore the concretion layer acts protectively and as stabilizing factor. If it is removed by mechanical abrasion, caused by water movement or human intervention, dissolved oxygen binds with the chloride rich acidic corroded surface and increases corrosion (MacLeod and Richards, 2011) (figure 6).

For that reason, (Bethencourt et al., 2018) argue that physical environmental conditions play a very important role in the preservation of iron shipwrecks. Corrosion rates rise in higher energetic conditions, where wave action is greater and might end in removal of the corrosion layers that act protectively. They state that is important to investigate the physical and hydrochemical conditions of a site because they affect the biological colonization dominated by algae or outnumbered by barnacles and polychaetes whose calcareous depositions are beneficial for the physical preservation of UCH.

Figure 6: Layer of marine growth upon an anchor. If it gets removed by human intervention, corrosion process might restart. (Jane Morgan, n.d.)

2.2 Human Impact

Human factors compete with natural factor as to which parameter proves to be more dangerous for the preservation of UCH. This is hard to be determined since it cannot be measured and is also influenced by cultural background. Edney (2006) investigated and classified human impact into two categories.

2.2.1 Indirect

The indirect category refers to conditions not related to recreational diving and are usually the result of development works, such as harbor and marinas constructions, modification of channels, dredging operations, oil extractions, beach replenishment, but also anchor damage and fishing activities. In the last case, a specific technique which even though is illegal, still occurs in some regions. This is dynamite fishing, which can cause damage both to the protective concretion layers of wrecks, for example, and to the wreck itself in mechanical way. Finally, an activity that involves diving but not recreational, is commercial salvage, which takes place after the sinking of a vessel in order to remove parts that are valuable, potentially useful or potentially harmful to the marine environment (Edney, 2006).

2.2.2 Direct

Concerning the impact of recreational diving, the first example is souveniring, the extraction of pieces for personal collection, ascribed with sentimental value or a sense of achievement. Moreover, in the past years, before the legal establishment of protection of (underwater) heritage, it was considered safer for the artefacts to be extracted on land (Edney, 2006).

The second and third types of direct impacts concern the diver’s physical behavior underwater. These refer mostly to direct contact with the wreck/site, either intentionally (e.g. for taking pictures) or unintentionally, deriving from unsecured equipment, poor buoyancy or wrong finning movements. The result is disturbance of the marine growth which acts as a protective layer, or mechanical damage to the material itself, while also causing alteration of its aesthetic value. Furthermore, even without contact, divers affect site just by their breathing: the exhaled air bubbles penetrating the wrecks can create vertical currents than may detach protective layers of marine growth and/or oxidation products, while also increasing the oxygen disposition, leading to further corrosion. Even though it has not been measured, it is a known danger among the scuba divers (Edney, 2006) (figure7).

The greatest danger however comes from anchoring. This may cause physical damage to the material, especially waterlogged timbers or detach the protective concretions and marine growth (Edney, 2006).

2.3 Climate change

Finally, natural factors have another potential to harm UCH in the future, due to the accumulative anthropic activity that leads to climate change. However, research on the effects of climate change on UCH is in initial stage. Perez-Alvaro (2016) describes the four main impacts, which are: i) Rising water temperature, which can lead to chemical changes (such as coral bleaching) and the overgrowth of *Teredo Navalis*. ii) Ocean currents and sediment movement, leading to mechanical abrasion and loss of historical information, iii) chemical changes affecting pH and salinity, iv) raising of sea level and the following alteration of depth, marine boundaries etc.

Figure 7: Wreck penetrating increases oxygen disposition and exhaled air bubbles create vertical currents of oxygen that could remove the protective concretion layer (David Kurkland, 2017)

3. PROTECTION METHODS OF UNDERWATER CULTURAL HERITAGE

Submerged cultural heritage carries both educational and recreational values, and for that reason is encouraged to provide access to researchers and the general public. At the same time, it needs to be ensured that the materials will be physically preserved for future generations. This is a fundamental principle, under which conventional museums and land historical sites have been operating for years. This chapter will describe the most common protection methods that address this notion underwater, against the natural and human threats.

The principles of these methods is the partial isolation of the material from its environment, thus disabling their reactions to oxygen, the shipworm and/or other borers which settle upon and feed from them, as well as distancing the object from direct contact with humans. For wood and stone, the methods usually involve covering with a proper material or reburial in the sediment. These methods are applied and examined with variations. The case of iron is different, where the protection that takes place is realized through a sacrificial method. Regarding human impact, researchers propose management strategies based on the two major methods that are able to control human behavior: legislation and education.

3.1 Protection against natural factors

3.1.1 Covering

i) Site stabilization with sediment

This method describes the creation of an anoxic/ suboxic environment by using the sediment movement in three different ways: sediment deposition with the use of geotextiles, shade cloth or rubber matting; sediment encapsulation with the use of cofferdams of wood, sheets of metal or polymeric crash barriers filled with sediment; and sediment trapping, using geotextiles, shade cloth, debris net or artificial seagrass (Richards, 2011) (figure 8). If the chosen material is net, the netting mesh opening should be selected according to the particles size of the sediment (Manders and Gregory, 2015). This method requires an optimal depth, a relatively flat bottom and regular, optimal currents. (Pešić, 2011)

Figure 8: Sediment trapping using geotextiles and artificial seagrass. (SASMAP Consortium, n.d.)

ii) Case- type

This type describes a complex box form, built from a metal framework that encloses the site to be protected. After it is fixed on the bottom, metal panels are assembled on every side of the frame and finally the inner area is filled with sand. These panels are moveable and can be removed during research. They provide divers during research the asset of working surface and safe navigation around the site. Moreover, they can be opened partially, while the rest of the site remains undisturbed. This method is suitable for long-term protection, small-scale and close-shape remains that require longer and systematic documentation (Pešić, 2011).

Similarly, a metal construction can also be built in cage form, made by steel netting, custom-sized, attached to the seabed and weighed down with concrete blocks to ensure stability. On top, lock openings are put for authorized personnel. It is efficient in protecting the site from direct access, while keeping it visible and self-explanatory if information plates are placed upon it. However, even if the netting has a protective coating of zinc to delay corrosion, its life span is only about 20 years (Pešić, 2011) (figure9).

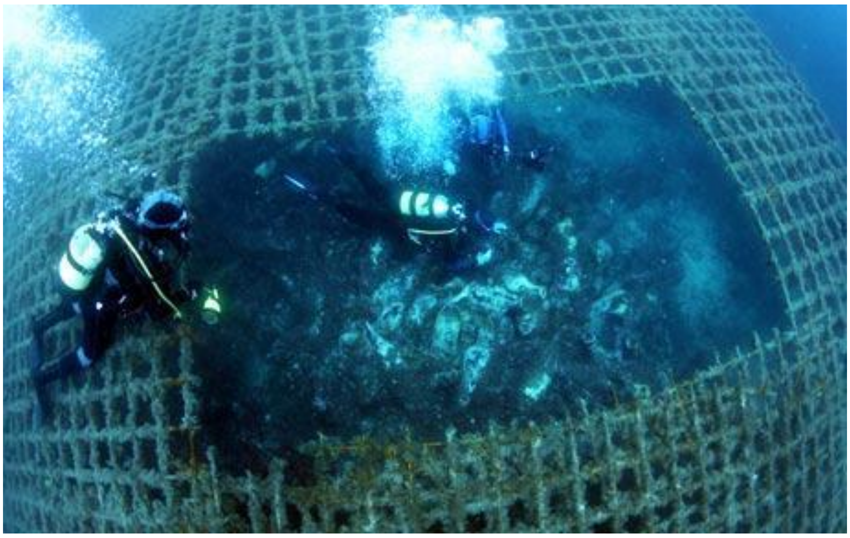

Figure 9: Cage- type protection for a 2nd AD Greek trading vessel in Croatia. (Neil Hope, 2010).

iii) Barrier/ Others

These methods involve wrapping materials directly around the timbers themselves. The materials used can be geotextiles, sand bags, geomembrane and PVC. They apply ideally on mosaic floors, architectural ruins etc., because they are easily removed for diver visits and maintenance procedures (Ricci and Davidde, 2012).

Another method is to use metal netting, from galvanized iron and coated in corrosion inhibitors. It needs to be affixed to the sea bottom with spikes or weighed down with concrete blocks. It is an economical and direct way to protect the site from intrusion. However it is only a temporary measure, since the netting itself, in the long term, can be susceptible to corrosion and marine attack and/or can be cut with tools. It is more effective when combined with other materials, such as: a layer of sand, polypropylene netting, a layer of gravel and sand, metal netting fastened to the bottom with spikes, a layer of heavier stones and even a top coat of seagrass for camouflage (Pešić, 2011).

Davidde (2004), supports that site stabilization with sediment methods are not suitable in relatively shallow waters, since the sediment is likely to be removed and the site re-exposed. It is also not recommended when the protected area is close to resorts that attract a lot of people and therefore may suffer vandalism or intrusion. Furthermore, sandbags are not recommended for long term *in situ* treatments because the choice of material (cotton, or UV stabilized polymeric sandbags) and the method of deployment are subject to alteration too (Richards 2011).

3.1.2 Restoration *in situ*

For submerged sites in Italy, regular conservation treatments such as cleaning and consolidation are a constant necessity. According to Petriaggi and Davidde (2012), in the Underwater Archaeological Site of Baiae, mechanical removal of biodeteriogens from walls and floors is realized by the use regular tools such as axes, hammers, chisels, metal spatulas etc. or pneumatic ones. In order to reach a refined result, a pneumatic micro-grinder (figure 10) can reduce large-size calcareous or carbon-based encrustations from the surface of the material. For restoration for masonry structures and the mosaic floors, a pneumatic mortar distributor was used for filling the cracks, testing different mortars in order to examine their hardening skills over the years and their reaction to sea conditions. Biological colonization can be fought by adding a biocide to the mortar dough, but has been reconsidered due to environmental ethics.

During the CoMAS Project (2011) they developed electrochemical devices to support more efficiently the aforementioned procedures. The tools designed specifically for performance underwater were a cleaning brush for loose deposits, with different shapes and sizes, a small electrical chisel for removal of carbonatic incrustations and demol24emolitionalcareous shells of bivalves in the sub fossil state and an electrical hand-held grinding tool to reduce carbonate encrustations thick and too hard to be removed by the small electrical chisel, for precised and controlled cleaning. (Bruno et al., 2015).

Figure 10: Removing biological encrustations using a pneumatic microgrinder in Baiae. (Petriaggi and Davidde, 2012)

3.1.3. Reburial

In other cases, where the local environment does not allow the application of these methods, a site can be excavated and the material redeposited, reburied in the same (*in situ*) or another (*ex situ*) environment, either in one piece or dismantled (Björdal and Nilsson, 2008). It may be wrapped in a form of plastic fabric, or deposited directly (Davidde, 2004). Reburial is defined as the natural or intentional backfilling of a site, in order to create anoxic conditions, where only slow microbial degradation will take place. Sediment can be deposited by boats but for the success of the method, there needs to be established beforehand that the sediments will not be removed due to sediment transport (Björdal and Nilsson, 2008). Finally, all the parts and items should be numbered and their position and surroundings thoroughly recorded before their reburial (Davidde, 2004).

According to Björdal and Nilsson (2008), reburial is an efficient method of protection. Specifically, after their investigations in the RAAR project in Sweden, they concluded that burial below 10 cm of sediment provided a less protective environment than with a layer of 42 cm. Based on this result, they recommend a reburial depth of at least 50 cm. Moreover, they suggest that a top cover of, for example, geotextile, would be appropriate to ensure long term stability and to prevent erosion of the sediment layer after reburial. Finally, they refer to the importance of monitoring the site in order to control the long-term security of reburial conditions. It becomes apparent that reburial and covering measures have the drawback of blocking/ excluding the direct sight of an object/ or site.

3.1.4 Cathodic Protection of ferrous elements.

The principle of this method, initiated by Ian MacLeod, consists of preventing the oxidation/anodic reaction from taking place in one area (the metal under protection), by channeling it to take place in another place. This is achieved by exposing a more electrochemically active metal, such as zinc, aluminum and magnesium. The metal is connected to the wreck and since it has lower Ecorr, it will serve as anode and corrode faster, and consequently delay the corrosion from the wreck (Davidde, 2004). The phenomenon is more intense if the difference between Ecorr values of the metals is high, and the surface area is small (Pearson, 1987). Additionally, the structure can be connected to an external electron source, called an impressed current. In this occasion, it nullifies the corrosion current and converts the corroding metal from anode to cathode. This current is connected to insoluble, anode- like graphite, stainless steel or scrap iron buried in the sediment (figure 11). Finally, as stated in section 2.1.3, marine growth provides a physically protective barrier between the artefact and the seawater by generating the formation of a microenvironment on the metal surface, beneath the concretion, which is substantially different from the open sea conditions (Pearson, 1987).

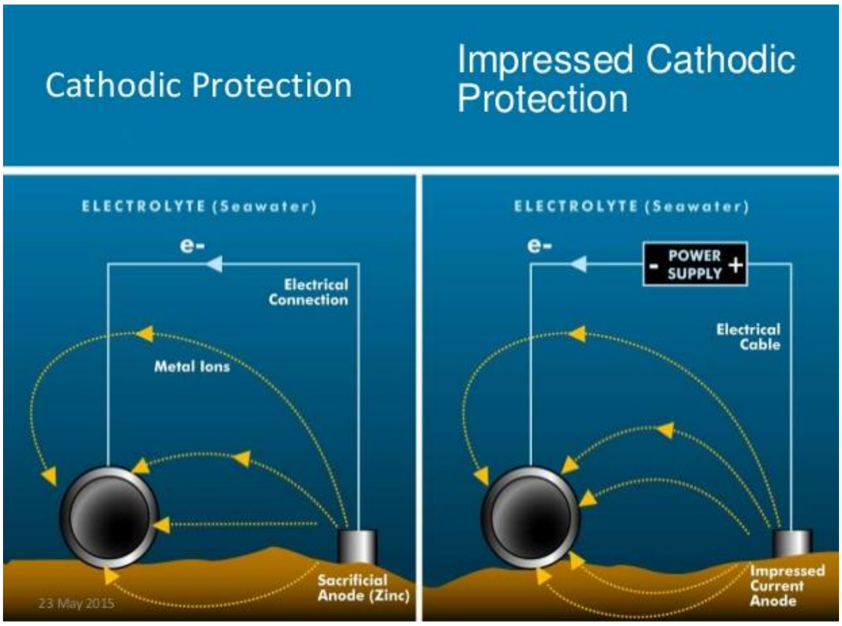

Figure 11: Cathodic and impressed cathodic protection. (CorrOcean, n.d.)

3.2 Protection against human impact

Harmful human impact on UCH can come from direct or indirect activities. Both can be dealt with by legal regulations and educational actions, as long as a management strategy that endorses these two is employed. Official state protection of UCH varies according to the legal system in every country, but in general marine archaeological areas and their surroundings are protected as part of the nation's cultural heritage as a whole. For better results, all countries that have not ratified the UNESCO Convention 2001, should align their national legislation with the Annexed Rules and act for its protection (Adewumi, 2014).

Legal protection measures include regulations about the discovery of a new wreck, site or artifact, (report to the authorities) and the guarding of existing ones as well. For the sea territory, such protection takes the form of prohibiting anchoring, fishing and dynamite fishing, trawling, and other boating and watercraft activities at the site and implementing an appropriate mooring system in order to avoid anchoring (Edney, 2006). This can be better achieved with the help of closed circuit TV cameras or anti-intrusion systems with luminous or alarmed buoys (Davidde, 2004).

Restrictions also include prevention against looting and souveniring. Delling and Endere (2001) describe the example of Argentina where if the marine archaeological area is not open to the public, but is open for survey, the divers/researchers should obtain authorization by the Coast Guard, be supervised by the divers of the Coast

Guard, and any finds must be given to the authorities. If the archaeological site is open to the public, recreational divers must be accompanied by a licensed guide and have their equipment and jackets checked on board after the dive. Additionally, the site must be monitored and surveyed (e.g. by sonar scanning) in order to check its condition. Violation of legislation can bring fines and imprisonment, but enforcement of the law is not always realized. This may be due to limited resources and superabundance of sites (Abd-el-Maguid, 2012), or due to cultural customary behaviors towards tourists, that do not allow for their mistreatment (Edney, 2006).

It's worth mentioning that these type of legal restrictions are not the case everywhere in the world. In some traditional communities, customary laws are more powerful than legislation and are used by the local community to endorse the protection of UCH and its surrounding environment, as it is a non-separable part of it. In particular, Ridwan (2011), argues that in Tulamben village, Bali, Indonesia, where the *Liberty* wreck is a world-famous diving site, the local community obeys to the customary laws called *Awig-awig.* They embody local wisdom and help people live peacefully and preserve their resources. In this case, they include prohibitions about fishing within 1000 meters of the shipwreck, removing the remains of the shipwreck, causing damage to the coral reefs attached to the shipwreck, as well as the stones around it, and cutting the plants around the beach. If someone violates these rules, they receive moral sanction, are ostracized from society and are not allowed to follow religious rituals.

Such moral values and customary ethics come to remind us that the most important driver for protecting something is to know about it, understand it and appreciate it. That way, an object or a site is treated as a common resource that requires collaborative work. When treated properly, it bears the possibility to bring benefits, both material for its keepers, and humanitarian, as cultural heritage is a common good and is preserved for the future generations. The best way to achieve this, most would argue, is through educational and outreaching activities to every stakeholders' group such as local small scale fishermen, the inhabitants, the city council, the dive operators, the (national) cultural heritage office, environmentalists and construction companies.

One of the most crucial groups are the ones that have the possibility to access UCH directly, and these are the divers. It is remarked upon that their attitude has changed significantly the last two decades in favor of the protection of UCH rather than as a field for competition and treasure hunting. However, it is still necessary to insert a heritage awareness programme in their training in order to eliminate undesirable situations. Scott-Ireton (2008) argues that such an education should emphasize the fact that damage to a shipwreck, for example, causes damage to the marine environment- which they are already eager and trained to protect. She mentions an example from the state of Florida where in a relevant seminar, a comparison between two different dives- one a looted shipwreck and one preserved- was employed in order to show the effects on the diving experience. In the case of the ravaged wreck, it was disappointing and uninteresting. Even more, divers have the ability to become actual guardians of the protected sites by monitoring and performing surveillance of the area, reporting any changes and even participate and conduct survey collection when necessary (Bendig and Budsberg, 2016).

Apart from the training of the diving community, public informal education should address all groups of citizens, for the most effective and widespread support of UCH (Secci, 2011) (figure 12). This can be achieved through posters, exhibitions, presentations, short-term courses, involvement of amateur archaeological associations and protection-oriented representation in media.

The key factor when reaching the public, as for every form of cultural heritage, is interpretation. Effective interpretation helps people appreciate what they see and improve the visitor's experience (Edney, 2006). For non-divers, it can be achieved through the production of literature such as brochures and pamphlets describing the resource. In the case of underwater museums, interpretation tactics follow the ones applied in open air museums (designed trails, informative panels, plasticized cards, guided visits in situ for divers and bottom-glass boat tours for non-divers) (Secci, 2011) (Scott-Ireton, 2007).

Figure 12: A "Maritime Bus" travelling around Cyprus and informing citizens about underwater archaeology (photogrph by the author, 2017)

4. ALTERNATIVE WAYS OF PRESERVATION

Apart from preservation of the material, there is another approach that reconstructs the original site/artefact by producing a physical or digital substitute. It is called informational preservation (Muñoz Viñas, 2012) and is based on records that preserve the most important pieces of information about the object. In this way, the observer can access the content without accessing the material.

4.1 Virtual dives

The quick expansion of digital technologies in the field of cultural heritage is an important asset for accessing UCH. Several projects have already been developed in order to assess digital documentation as a tool for marine archaeologists or in order to make a site accessible to general public or both. These projects also explore the potential of such technologies to reconstruct both the aquatic environment and the submerged features in a realistic way that will transmit the unique feeling of an underwater experience.

One of these projects was VENUS (Virtual Exploration of Underwater Sites, sponsored by the European Community) which aimed at the virtual exploration of deep underwater archaeological sites which are inaccessible by humans. According to (Haydar et al., 2011), the virtual environment is constructed according to a database that contains all the information that bathymetric and photogrammetric surveys, with remote operated or autonomous underwater vehicle have collected, such as photos, artefacts parameters, 2D/3D objects' location. These can be retrieved using familiar tools on the interface, such as menu bar, information panel and popup message.

Haydar et al. (2011) argue that archaeologists examine two things, when it comes to shipwrecks: the cargo and the environment. For that reason, the virtual environment is designed to allow the performance of three functions:

- Visualization: full view and close range
- Navigation: free navigation, artefact- based navigation or diver's navigation, with two main components: travel and way finding, including the choice of direction or target, motion speed/ acceleration and entry conditions.
- Interaction: artefact's individual data facts, inventory and artefacts statistics in terms of types, dimensions, location and fragment status for broken artefacts with the gathered data by connecting tools in the Virtual Environment to an underlying archaeological database.

Both VR (Virtual Reality) and AR (Augmented Reality) technologies were used. VR technology offers the possibility of immersion within multimodal interactions (audio, video and haptics) to enhance user involvement. On the other hand, AR or mixed reality technology provides the possibility to extend, transform and combine different cultures in the same mixed environment. Also, tangible AR interfaces might be employed and contribute to an even more realistic interactive experience and so enhance natural interactions in order to access and manipulate information with functions such as selection tool, measuring tool, inventory tool and grid tool (Haydar et al., 2011) (figure13).

Figure 13: Tangible Interface of AR Venus (Haydar et al. 2008)

Similarly, even though not in such depth, but still under physical and operational restrictions, the 4th-century BC Mazotos shipwreck in Cyprus, viewed a digital version as an opportunity for archaeologists and researchers to study the wreck and eventually investigate the potential for interpretation and analysis for underwater archaeology.

An immersive 3D visualization application that utilizes a VR CAVE (Virtual Reality Cave Automatic Virtual Environment) technology was developed. The users were able to navigate through the virtual environment, display information and images related to an artefact, select individual artefact, load amphorae textures, load and manipulate hypothetical seabeds, load the predisturbance seabed, load and manipulate fixed amphorae (moving and rotating them and positioning them in a predefined location using the grids) (Katsouri et al., 2015). The most highly appreciated features, according to user evaluation, were the loading of amphorae textures and the scale tool. Also, the users reported that the application is time-effective and retains the feeling of examining the actual site underwater, as opposed to other methods used so far. However, they stated that such an application could not be used independently from the information they have collected physically and from traditional research methods. However that might be a matter of training and exposure to such technologies (Katsouri et al., 2015).

A more visitor oriented is the VISAS project: Virtual and augmented exploitation of Submerged Archaeological Sites, a collaborative research project funded by MIUR (Italian Ministry of Education, University and Research). Based on new technologies and methods it aims to improve the visitor experience and enjoyment of underwater archaeological sites, as a recreational and also educational experience. For that reason, it was approached with a user centered design (UCD), VR systems for ultimate experience and an user friendly platform (interface) addressed to all kinds of audiences, and not only the technologically familiar. (Bruno et al., 2017).

The site preserves the wreck of a Roman cargo ship at a depth from the sea level ranged from 25 to 30 meters and the site is characterized by a complex morphology. According to the authors, the scene is composed from both the sunken ship, and the surroundings, including 3D models of the flora and fauna typical of the specific marine ecosystem. The interest area of each feature (called points of interest POIs) is indicated by color signs e.g. yellow for the historical and archaeological information and green for biological ones. Finally, additional acoustic and visual graphic effects were applied, such as refractions, fog, caustics of the particulate, etc. in order to make the environment even more realistic.

The application offers the possibility for the visitor to choose between a free and a guided tour. Its basic difference is that in the first mode, the user has no time limit and can navigate to any direction and interact with the POIs freely, while on the second she/he is subject to real-life limitations. A safely conducted scuba diving session is determined principally from the air contained in the diving tank and the decompression stops that prevent from narcosis. Consequently, the user can visit the pathways/ routes that the remaining air supply indicates and therefore, the time underwater. (Bruno et al., 2017)

A precursor of this project, with a holistic, user-centered design was employed in Finland. Users were able to gesturally navigate around the wreck of Vrouw Maria, a Dutch merchant ship that sank near the Finnish coast in 1771 and remains underwater, well preserved, in 41 meters deep in a natural reserve area. The main features of the immersive application were: Real- scale graphics based on images and measurements obtained from the site, immersive stereoscopic display consisting of a back-projected screen and polarized goggles, gesture-based interaction, immersive soundscape that changes according to time and depth and fifteen info spots offering further details on the site (figure14). The constructed scenarios addressed three main groups of museum goers: foreign visitors, marine enthusiasts, and schoolchildren who visit the museum with their teacher (Reunanen et al., 2015).

Figure 14: Virtual test-dive of the Vrouw Maria shipwreck (Reunanen et al., 2015)

According to the authors, the users managed to navigate to the rear of the ship, find the main cargo bay, discover the cargo bay contents and exit, find information on the masts, go to the sea bed and return to the ship. They indicated some problematic features, regarding initiation (calibration and instructions), gesture tracking, vertical navigation, stopping, exiting and getting lost when far from the ship.

From this brief overview of representative case studies where Virtual Reality technology is the most prominent, we observe that “virtual dives” appeal both to professionals and general public. They have the possibility to simulate the most important features of an underwater visit, and therefore assist, educate and entertain on demand. Museum visitors, are not passive viewers, but participate actively through interactive functions. At the same time, the actual site remains safe in the determined preservation conditions and its natural surroundings remain undisturbed. As Styliani et al. (2009) state, virtual museums seem to be ideal in serving as ‘’digital reflections’’ that do not replace the actual sites, but act complementarily and carry the values and messages of real museums.

4.2 Recreational cultural dives

Alternative museums that operate in favor of the preservation of UCH are not only virtual. Under the water surface, there is an emerging new type of diving parks, that combine recreational and heritage values, by submerging contemporary sculpture designed and constructed especially for that purpose.

The most popular case is MUSA (Museo Subacuático de Arte), located in the waters surrounding Cancun, Isla Mujeres and Punta Nizuc, in the Caribbean Sea, Mexico. It consists of over 500 permanent life- sized and monumental sculptures, made from specialized materials to promote coral life. (MUSA 2016). These materials are mainly made of a special type of marine grade cement “pH neutral clay”, which serves as an artificial reef for corals to settle and grow upon, and eventually allow marine life to flourish. (El Gohary, 2013).

Moreover, the message they convey under artistic scope, attempts to restore a lost equilibrium not only in the marine environment, but also in modern human societies. James Decaires Taylor’s artwork aspires to problematize visitors upon the era of Anthropocene: the impacts of modern life on nature, with climate change being the most dominant (Picken, 2016) (figure15).

So far, this is a successful project that reveals its values in multiple layers: ecological, educational, recreational, touristic, social and aesthetic. Consequently, professionals in the protection of historic submerged heritage can get inspired by such projects. In cases where exposing the sites becomes harmful for material preservation, the original ones may be replaced with replicas. A successful example can be seen in the Underwater Archaeological Park of Baiae, where copies are exhibited in the positions where the original statues were found, while preserving *in situ* mosaic floors and other architectonic features (Stefanile, 2014) (figure16). Alternatively, diving parks for contemporary heritage might be created, made from eco-friendly materials, that will distract the public from fragile archaeological and natural areas (Davidde, 2004). There seems to be a potential in this kind of method which stirs tourist demand for cultural experiences away from the original vulnerable sites, as long as this demand is relatively undiscriminating. Throsby (2009) mentions that a similar suggestion had been made for the case of Venice with the construction of a Disney-style attraction near the city as a measure to cope with the negative effects that mass tourism has brought.

Figure 15: Anthropocene, submerged sculpture by Jason Decaires Taylor (MUSA, 2016)

Figure 16: Copy of a statue exhibited in the underwater archaeological park of Baiae. (Giovanni Salera 2016)

5. DISCUSSION

Assessment of methods and strategies

After examining the threats of UCH and the methods that have been developed for preservation *in situ* according to Rule 1 (see chapter 1), it is essential to discuss the case where public access is incompatible with protection and management, as referred to Rule 7 (see chapter 1). An overview of the protection methods of UCH is outlined in Table 1.

Table 1: Protection methods of UCH

PROTECTION METHODS OF UCH	
MATERIAL PRESERVATION	INFORMATIONAL PRESERVATION
Covering	Virtual dives
Reburial	Recreational diving parks
Restoration in situ	
Cathodic protection	
Legislation & Education	

Such cases concern mainly the sites or objects made of wood or marble. As mentioned in chapter 2.1.1, studies on the degradation of wood warn about the destructive action of the shipworm that lives in oxygenated waters and feeds from the cellulose. These propose burial in the sediment as the most effective solution. Similarly, the case studies and experiments on marble units and artefacts showed a rapid biological colonization when they were exposed in the sea column, as opposed to having been placed in the sediment.

For that reason, it is advisable for the sites or objects consisting of these materials, to be reburied in the sediment or covered according to established techniques, rather than being exhibited *in situ* as a visitor attraction. Otherwise, there is a high probability of material deterioration and consequent aesthetic alteration and loss of archaeological information, which is opposed to the conservation ethics that stand for the perpetuity of knowledge. (Davidde, 2004) argues that the most effective method for wrecks, 'from a conservation standpoint' is the case-type system for four main reasons: 1) it doesn't burden the material/site under protection, 2) it protects from trawlers and anchors, 3) it blocks the light and consequently phototrophic microorganisms and 4) it can be dismantled and reused. She also proposes that the most suitable heritage sites to exist in the context of an underwater park are: iron wrecks, that are protected by sacrificial anode and lithic architectonic submerged features to which *in situ* restoration methods can be applied repetitively or be partially covered. In any case, all these preservation and exhibition conditions require constant monitoring and maintenance procedures.

When a site or object is protected *in situ* by a reburial method, its content still can be accessed by researchers or general public by informational preservation. Either in a virtual environment or by replacing the original artefacts with an underwater exhibition of copies. This method guarantees that the originals' exposure to human and natural threats is highly reduced. However, (Muñoz Viñas, 2012) points out two aspects of informational preservation that should be taken under consideration when addressing this technique. The first one, is the fact that actual preservation of the original material still remains necessary (in other words, informational preservation is an additional measure for conservators, but not a direct solution). The second aspect is that duplication may eradicate the unique, non-replaceable character of the originals. Finally, he mentions that the visit to a heritage site that consists of replicas or digital reconstructions, degrades the authenticity value from the site, which observers describe as a powerful and non-comparable experience.

Noticing that the virtual environment lacks authenticity and the marine environment lacks stability, *in situ* protection should not be considered as a permanent or all-embracing protection measure. Lu and Zhou (2016) argue that Article 2(5) of the 2001 Convention instructs that preservation *in situ* should be adopted as a first option ''before allowing or engaging in any activities directed at this heritage'' and this implies that preservation *in situ* is a type of temporary management strategy before recovery. For that reason, after examining the case of China's strictly state-led model of protection of UCH, they propose commercial enterprises or the private sector to be allowed, in certain circumstances, to conduct excavations of UCH that will closely follow archaeological standards and will be supervised by both government officials and archaeologists. There is an economic benefit integrated into cultural resources, that when salvaged and exhibited in museum institutions, they can recover the cost and investment for private entities and become income resources. Furthermore, they argue, that museum exhibitions promote better preservation, protection and security conditions for the artefacts and accessibility to the general public including the disabled and old.

As *in situ* preservation is not always the appropriate solution, increased awareness and public promotion are not always harmless too. If not managed correctly, they may attract the wrong kind of attention and unwanted kind of visitors. (Duarte, 2012) refers to media operators, including some prestigious ones such as *National Geographic* and *Discovery* that still reproduce the image of treasure hunting when it comes to underwater archaeological operations, covered with a misconception of legitimacy (figure17). As a result, uncoordinated scuba diving tourism and careless tourist agents can step on this line of thinking in order to achieve their own greater profit. Finally, salvage and unsupervised commercially-oriented interventions may occur, with well-known negative effects: black market and illicit trade of cultural property (which includes underwater relics) ranks third after drugs and weapons.

Figure 17: A TV show about marine expeditions called "Treasure Quest" (Netflix n.d.)

The operation of diving parks in marine archaeological areas establishes the right of public access to UCH sites. However, exhibition *in situ* may not always be aligned with material preservation. For that reason, the following remarks should be taken into consideration:

- Exposure of wood and marble in the sea column is highly probable to lead to their deterioration. Therefore, their reburial or covering should be implemented.
- Informational preservation, physical or digital, is a valuable alternative way to communicate the content of a site. Nevertheless, it should be handled with caution in order to avoid 'disneyfication' phenomena of heritage.
- Legislation and education are powerful tools for eliminating the human threat on UCH.

Underwater archaeological parks are an essential feature of UCH management, since they promote the fundamental right of public access and bring socio-economic benefits to the local communities. Nevertheless, their operation should not put in danger the physical integrity of UCH, since it contradicts the actual purpose of conservation and can lead to irreversible loss.

6. CONCLUSIONS

The literature research conducted for the purpose of this thesis delivered an important amount of information that reveals the complexity of the matter of public access and preservation of UCH. Constructive synthesis of these results can give answers to the research questions set for the purpose of this thesis and are formed as follows:

What are the main threats of UCH?

Threats of UCH are broadly divided in 1) Natural factors, that include water currents and sediment movement that affect mechanically an object or site, and characteristics such as oxygen, pH and temperature that affect the growth and distribution of marine borers and microorganisms that live in the marine environment and settle upon and feed from the materials that compose submerged historical sites. 2) Human impact, that can be indirect through construction works, moorings, fishing and anchoring, or direct through souveniring and diver's physical behavior underwater. 3) Climate change accelerates and accentuates the natural factors described. This question helps in understanding the concept behind the development of the established protection methods, summarized by the following question.

What are the protection strategies for UCH and how do they relate with public access in situ?

Protection strategies for the physical preservation of wood and marble are mostly based in covering the site or object with several materials or burying it approximately 50 cm into the sediment. This leaves other kind of lithic materials and iron to be more appropriate options for exhibition in situ. Specifically, architectonic features can be restored *in situ* with pneumatic or electromechanical tools. Ferrous materials can be protected by the installation of a sacrificial anode and/ or by maintaining the concretion layer formed, which acts protectively in the long term. All these methods require constant monitoring and maintenance procedures in order to reassure the desired conditions. In sites that are highly energetic, preservation and/or exhibition *in situ* might be a short term management option rather than a long term one. In any case, UCH is and should be protected legally and the official state should raise awareness about its preservation through outreaching activities.

Are there alternative ways to preserve and exhibit UCH?

For physical preservation, excavation and recovery is still an option if the other methods fail. If it is not possible, the site/object can remain underwater in the determined conditions, but public access will not be realized *in situ*. It can be achieved with virtual dives in a digitally reconstructed environment. Otherwise, exhibition *in situ* can be composed of replicas. Alternatively, creation of thematic underwater parks- preferably from eco-friendly materials- can be made in order to distract cultural tourism from fragile heritage sites and direct them to contemporary ones.

In conclusion, the long-term effects of diving parks in marine archaeological areas on the preservation of UCH are:

- Beneficial for the protection of UCH, when they are consisted of materials that are resistant to the site conditions and all the necessary protection measures are employed. Combined with knowledge awareness centers in close proximity to the site on land and wide range educational strategies, underwater archaeological museums promote interdisciplinary collaboration, research on conservation and bring financial benefits. UCH is not a renewable source, but with the assistance of new technologies and outreaching management generates a resourceful potential.
- Non-beneficial, when public access *in situ* is uncontrolled and UCH is seen only as a way for easy profit rather than a common cultural trust for future generations.

Way forward

Towards an effective decision-making process for the protection of UCH there are several issues that still remain unclear. Future research should examine the long term effects of burial or exposure to the sea column on several materials and this thesis aspires to be a first step towards this direction. Furthermore, the impacts of climate change should be investigated and a statistical study that could quantitatively describe the empirical data for the benefit of public inclusion in the protection of UCH could be conducted.

Official establishment of underwater archaeological parks grants public access and embodies the human right to enjoyment of cultural heritage. Nevertheless, it is necessary to evaluate each and every site independently in line with all the above mentioned characteristics and act accordingly.

SUMMARY

The topic of this thesis is the review of current protection methods for UCH and the way underwater sites can be accessible to the public, while ensuring their physical integrity, according to the UNESCO 2001 Convention. These notions seem to contradict each other, since the exposure of the materials in the water column generates and/ or accelerates their degradation. Therefore, the research question studies the long-term effects of diving parks in the preservation of UCH. For the purpose of this project, three representative materials are examined through literature research: wood, stone and iron.

Specifically, wood consists of nutrition source for marine borers that live in oxygenated waters and create long cavities in the interior. It is also attacked by fungi and bacteria that feed from the cellulose and hemi-cellulose and turn its surface soft. Environmental parameters, such as oxygen, salinity, temperature affect the presence and distribution of borers and micro-organisms, while water and sediment movement can mechanically damage the material. Similarly, lithic materials are subject to biological colonization that acts both chemically (bioerosion) and mechanically (bioabrasion). Ferrous materials form iron oxides due to their contact with the oxygen contained in the seawater. They also get covered by a layer of marine growth which eventually, and if not disturbed, acts protectively because it partially blocks the exchange of electrons between the metallic surface and the seawater.

The principles of the protection methods are based on the partial isolation of the material from its environment, thus disabling the reaction to oxygen, the borers and microorganisms settling upon and feeding from them, as well as the distance of the object from direct contact with humans. For wood and stone, the methods usually involve covering with a proper material or reburial in the sediment, including variations with materials such as geotextiles and artificial seagrass, or case type constructions. When it comes to architectonic features, restoration with mechanical methods, such as cleaning and consolidation may also be applied. Different is the case of iron, where the protection can be realized through a sacrificial method. In every case, maintenance procedures and monitoring are essential for controlling the preservation conditions in the long term. Regarding, human impact, researchers propose management strategies to be designed on the two basic methods that are able to control human behavior: legislation and education.

Alternatively, informational preservation is an emerging sub-discipline that can combine material preservation and accessibility. Virtual dives ensure that the materials, either in very deep locations or buried in the sediment, remain safe while the professionals or the public access the information and even interact with the site in a digital environment. In a different case, if SCUBA diving and/or glass-bottom

guided tours are desired, an underwater exhibition of copies or thematic park can be realized. In that way, the visitors can still experience the feeling of visiting submerged sites and their current location, navigate in the marine park and at the same time, boost the local economy.

However, every case is as unique as the sites/objects and environmental conditions involved and for that reason protection and exhibition methods need to be evaluated accordingly. *In situ* preservation methods show lower performance in higher energetic conditions and digital reconstructions lack authenticity. Furthermore, excessed media exposure of UCH can attract the wrong kind of attention and generate counter-results.

The tremendous and constant progress of research protection of UCH has given answers to many important questions, indicating the risks of the marine environment and employing all the available tools for its protection or exhibition. However, there is still need for long-term research and experience on a broad spectrum of materials and high-energy environments. Climate change is also a constant threat that needs further investigation, and human impact needs to be recorded with statistical data and not only empirical.

It becomes apparent that the physical protection of the materials that constitute UCH rather frequently comes in conflict with public access and deciding on a strategy that maintains the balance is challenging. For that reason, the following remarks should be taken into consideration in decision-making processes: a) Exposure of wood and marble in the sea column is highly probable to lead to their deterioration. Therefore, their reburial or covering should be implemented. b) Informational preservation, physical or digital, is a valuable alternative way to communicate the content of a site. Nevertheless, it should be handled with caution to avoid 'disneyfication' of heritage. c) Legislation and education are powerful tools for eliminating human threat to UCH.

In conclusion, the operation of diving parks in marine archaeological areas should not put in danger the physical integrity of UCH, since it contradicts the actual purpose of conservation and can lead to irreversible loss. If they are consisted of materials that are resistant to the site conditions and all the necessary protection measures are employed, they can have beneficial long-term effects. Combined with knowledge awareness centers in close proximity to the site on land and wide range educational strategies, underwater archaeological museums promote interdisciplinary collaboration, research on conservation and financial benefits. UCH is not a renewable source, but with the assistance of new technologies and outreaching management generates a resourceful potential.

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