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THETIDA: Safeguarding Underwater and Coastal Cultural Heritage through Innovative and Inclusive Methodologies

Anais Guy^{a*}, Annalisa Donati^b, Panagiotis Michalis^c, Deniz Ikiz Kaya^d, Vassilia Karathanassi^e, Sónia Oliveira^{fg}, Claudio Mazzoli^h, Flávio Martinsⁱ, Michele Cocco^j, Tina Katika^k Angelos Amditis^l,

^a *Eurisy, 52 rue Jacques Hillairet, 75012 Paris, France, anais.guy@eurisy.eu*

^b *Eurisy, 52 rue Jacques Hillairet, 75012 Paris, France, annalisa.donati@eurisy.eu*

^c *Institute of Communication and Computer Systems (ICCS), Iroon Politechniou 9, Zografou 15773, Athens, Greece, p.michalis@iccs.gr*

^d *Eindhoven University of Technology, Vertigo building, PO Box 513, 5600 MB, Eindhoven, the Netherlands, d.ikiz.kaya@tue.nl*

^e *National Technical University of Athens, Heroon Polytechniou 9, 15780 Athens, Greece, karathan@survey.ntua.gr*

^f *Centre for Marine and Environmental Research (CIMA/ARNET), University of Algarve, Campus de Gambelas, 8005-139 Faro, Portugal, saoliveira@ualg.pt*

^g *Centro Ciência Viva do Algarve, Rua Comandante Francisco Manuel, 8000-250 Faro, Portugal, soliveira@ccvalg.pt*

^h *Dept. of Geosciences, University of Padova, via Gradenigo 6, 35137 Padova, Italy, claudio.mazzoli@unipd.it*

ⁱ *University of Algarve, Campus da Penha, 8005-139, Faro, Portugal, fmartins@ualg.pt*

^j *EdgeLab s.r.l., via della Ferriera 1, Portoferraio 57037, Italy, michele.cocco@edgelab.eu*

^k *Institute of Communication and Computer Systems (ICCS), Iroon Politechniou 9, Zografou 15773, Athens, Greece, tina.katika@iccs.gr*

^l *Institute of Communication and Computer Systems (ICCS), Iroon Politechniou 9, Zografou 15773, Athens, Greece, a.amditis@iccs.gr*

* Corresponding Author

Abstract

Coastal areas have always been the cradle of primary social communities, and ancestors of modern society, owing to numerous resources including fishing and trade. These communities left a footprint, a testimony of our evolution, that is now an integral part of our cultural heritage and embodies their livelihoods and values. Nonetheless, coastal areas have always been exposed to natural hazards, and the effects of climate change exacerbate the threats to coastal and underwater heritage, threats that can be monitored and anticipated through space capabilities. As part of the THETIDA Horizon Europe project, 17 partners collaborate to develop and connect innovative technologies and participatory processes in seven underwater and coastal heritage sites, selected to represent diverse climatic conditions.

The THETIDA project aims at promoting, testing and demonstrating innovative and sustainable modelling tools and decision support systems to protect coastal and underwater cultural heritage from climate change and other hazards, and to respond efficiently to those risks. Taking full advantage of the Copernicus Climate Change Service to model and predict the impacts of climate change on the sites, the tools developed will enhance stakeholders' awareness, response times, and efficiency, and provide the basis for evidence-based and inclusive decision-making through the Living Labs (LLs). The THETIDA LLs are multi-stakeholders platforms and interaction spaces in which multiple actors meet, co-create future scenarios, and build roadmaps for a climate-resilient future of heritage sites.

This approach is supported by Earth Observation (EO) and InSAR satellites, complemented by in-situ sensors, enabling partners to identify and map climatic risks. The data fuels LLs, allowing local stakeholders to make evidence-based decisions, as well as to involve in data collection through citizen science tools. LLs enable partners to understand local stakeholders' needs and to tailor relevant policies and strategies accordingly. Diversity and inclusivity are key to ensure that all facets of the cultural heritage site are covered.

This paper aims to provide first-hand examples of local stakeholders' and end-users' active engagement and to illustrate how cultural heritage can support the uptake of space capabilities. It demonstrates how the holistic and user-centred approach of THETIDA enables the development of multiple hazard assessment tools answering to actual stakeholders' needs. Motivated by a growing demand from European actors and a momentum on cultural heritage, the THETIDA project recognizes contemporary users' needs and acknowledges the peculiar and central role of cultural heritage in communities, and the necessity to preserve it to build a climate-resilient future.

Keywords: Cultural Heritage; Preservation; Climate Change; Innovation; Inclusivity; Participatory Processes.

Acronyms/Abbreviations

AR	Augmented Reality
EO	Earth Observation
EGD	European Green Deal
CH	Cultural Heritage
CAMS	Copernicus Atmosphere Monitoring Service
CLMS	Copernicus Land Monitoring Service
CMEMS	Copernicus Marine Environment Monitoring Service
Copernicus EMS	Copernicus Emergency Management Service
C3S	Copernicus Climate Change Service
ICOMOS	International Council on Monuments and Sites
LLs	Living Labs
OMC	Open Method of Coordination
UCH	Underwater Cultural Heritage
UN	United Nations

1. Introduction

Europe's underwater and coastal cultural heritage faces numerous threats from natural hazards and the impacts of climate change. From coastal erosion to sea level rise and ocean acidification, these pressures could lead to the destruction and disappearance of coastal heritage and accelerate the deterioration processes of underwater cultural heritage, resulting in the loss of Europe's rich and diverse legacy [1].

Experts and researchers urge for an increased awareness on the vulnerability of cultural heritage sites, and an integrated risk monitoring system to ensure their protection. The existing knowledge on and understanding of the impacts of climate change on cultural heritage, including underwater and coastal heritage, is still limited, and data derived from recurrent risk monitoring is often not included in conservation and site management plans. [2].

Addressing this gap with efficient and evidence-based solutions, the THETIDA project, funded under the European Commission Horizon 2022 *Effects of climate change and natural hazards on cultural heritage and remediation* call, aims at safeguarding and protecting Europe's coastal and underwater cultural heritage from the effects of climate change and natural hazards by integrating innovative methodologies and cutting-edge modelling.

The project develops around a holistic approach to the preservation of cultural heritage including methodologies addressing risk assessment and management, protection, and preparedness. THETIDA hence designs and implements a preventive conservation strategy to prevent damages to coastal and underwater heritage sites,

identifying and warding-off threats, promoting policy tools fostering climate neutrality and economic resilience. To ensure the effectiveness and sustainability of the strategy devised, the project is driven by a European multidisciplinary team of researchers, experts, and practitioners building, testing and validating an integrated multiple risk assessment and protection system based on evidence-based monitoring frameworks, innovative tools and participatory processes such as citizens' science and Living Labs (LLs).

Representing the diversity of Europe's underwater and coastal cultural heritage sites, as well as the varying socio-economic impacts of the sites on local communities, THETIDA is comprised of seven pilot sites. Each pilot site functions as a living laboratory throughout the project duration, to interact, test, and validate the innovative tools and services developed throughout the project.

Two of the four underwater pilot sites are located in the Ligurian Sea (Italy), representing western Mediterranean environmental conditions. The first site is the Equa shipwreck, a World War II (WWII) submarine chaser that sank in 1944. The second Italian pilot site is the 1st century Roman Albenga shipwreck, one of the largest known Roman merchant vessels. The heritage is situated in a protected area around Gallinara Island, where tourism is strictly limited. The B-24 Liberator, a crashed WWII American four-engines aircraft along the Portuguese coast has been selected to cover the Atlantic Ocean. Nissia, located in Cyprus, is a 18th-century Ottoman shipwreck that lies at a depth of 27 meters in the Eastern Mediterranean Sea. In addition to these underwater sites, the THETIDA project also focuses on three coastal sites: IJsselmeer is a closed-off freshwater lake in the Netherlands, the Castle of Mykonos Town in Greece, and the Hiorthhamn Coal Cableway station in Svalbard, Norway. These coastal pilot sites respectively exemplify Northern European environmental conditions, Mediterranean environmental conditions, as well as Arctic environmental conditions.

2. Balancing cultural heritage as a sovereign right and climate adaptation incentive

2.1 Current definition of cultural heritage and international recognition of its intrinsic values

Cultural heritage is defined both as a process and produce that is comprised of both tangible and intangible assets and expressions of human life [3]. The broadened definition of heritage stated in Art. 1 of the Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention), adopted by the general conference of the United Nations Educational, Scientific and Cultural Organization

(UNESCO) at its seventeenth session in 1972, focusing exclusively on material cultural and natural heritage, has indeed been complemented in 2001 by the Convention on the Protection of the Underwater Cultural Heritage, acknowledging the specific benefits of underwater cultural heritage (UCH) for society.

In the early 2000's, the value of cultural heritage was formally recognized at the European level through the Convention on the Value of Cultural Heritage for Society (the so-called Faro Convention), adopted by the Committee of Ministers of the Council of Europe on 13th October 2005. The Faro Convention emphasizes the link between cultural heritage and universal values, such as human rights and democracy, acknowledging CH as a part of Art. 27 of the 1948 Universal Declaration on Human Rights (UNDHR) [4].ⁱ The Convention systematises the elements of the “common heritage of Europe”. The principles set within the Convention aim to ensure that cultural heritage contributes to the social and economic development of EU Member States, emphasising cultural heritage's crucial role in tearing down barriers and building social cohesion, boosting integration, and promoting dialogue for a more resilient European society. Europe counts the highest number of cultural and natural sites assigned UNESCO's World Heritage status globally [5]. According to Eurostat, in 2023, about 7.8 million people were employed in the cultural industry across the EU, totalling 3.8% of the overall employment figure for the region. Europe is the global leader in international tourism, accounting for roughly 60% of international tourist arrivals worldwide in 2022 [6]. This is reflected in the share tourism contributes to Europe's GDP, reaching 10% in 2022 as well as to numerous indirect impacts on socio-economic factors.

2.2 Including cultural heritage within European policy priorities

Whilst policymaking in cultural heritage seats primarily within the portfolio of competencies of Member States, the European Union is yet competent to assist and complement national legislations. The European Union's role in this domain thus consists mainly in gaining intelligence to devise strategic frameworks outlining major goals to be achieved by the region through Work Plans, Agendas, Programmes,

ⁱ Faro Convention (2015, art. 1(a)): the Parties to the Convention recognise that “recognise that rights relating to cultural heritage are inherent in the right to participate in cultural life, as defined in the Universal Declaration of Human Rights” and UNDHR (1948, art. 27(1)): “Everyone has the right freely to participate in the cultural life of the community, to enjoy the arts and to share in scientific advancement and its benefits”.

Reports, and Recommendations aiming at prioritising the actions and favouring exchange and cooperation. Within the Council conclusions on the Work Plan for Culture 2019-2022 (2018/C 460/10), the Council of the European Union (the Council) recognized the horizontal role of **digitalisation** and the innovative possibilities it creates **for access, preservation, and dissemination of cultural heritage** [7]. A position shared by the Special Rapporteur in the field of cultural rights to the United Nations, Prof. Karima Bennouna, and expressed in the Report A/75/998 presented at the 75th session of the General Assembly of the United Nations (UN) in 2020.ⁱⁱ The Council of the European Union emphasized the need for a comprehensive approach to preservation and safeguarding of cultural heritage, a core strategy of THETIDA, to ensure the viable future of Europe's cultural heritage. It is worth noting that the Council also highlighted participatory governance as a recommended action for the sustainable management and valuation of cultural heritage. On the subject of adaptation to climate change, *mapping exercises* – intended as multi-stakeholders and multi-disciplines interaction platforms to exchange experiences, best practices, and lessons learned from diverse experiences related, lead to “awareness-raising and capacity-building of national heritage experts on the sustainability of cultural heritage” [8]. The Council envisages mapping exercises as a tool to exchange knowledge and best practices on historical environment and climate change effects. To lead actions on the field, an Open Method of Coordination (OMC) group of Member States' experts was established to strengthen cultural heritage resilience to climate change [9].

The 2019-2022 Work Plan has been specified and reinforced in the Plan for 2023–2026 (2022/C 466/01), which highlights as priorities “culture for the people: enhancing cultural participation and the role of culture in society” and “culture for the planet: unleashing the power of culture” [10]. The legislator emphasises here the relevance of intensifying a broaden citizen participation, promoting a stronger engagement of the whole community in decision-making, creation, and production of policies and actions. It also emphasizes the need for strengthened risk-assessment instruments, improved disaster preparedness, and coordinated actions, which require further integration of cultural heritage into wider policies and initiatives at all levels [11].

ⁱⁱ Report A/75/298 (2020), Recommendation (f): “Embrace and leverage the role of data in measuring climate change-induced destruction of all forms of culture and cultural heritage, and in protecting and restoring culture and cultural heritage following such damage”.

As guiding principles for 2023-2026, the Work Plan considers the significant contribution of culture, and cultural heritage, to sustainable development, the economy, and social inclusion.

Although the European Green Deal does not explicitly mention cultural heritage, the International Council on Monuments and Sites (ICOMOS) published the European Cultural Heritage Green Paper in 2022 focusing on the specific role cultural heritage holds in achieving the EGD goals and providing recommendations to policymakers and heritage operators [12]. Complementarily, the European Commission launched the New European Bauhaus initiative in 2021 to bring inclusive, creative, and cultural values to the green transition.

As a European Commission-funded project, THETIDA embodies Europe's ambition to foster multidisciplinary research, innovation, and development in the field of cultural heritage, climate change adaptation, and overall sustainable development. Through international cooperation among its partners, the project is poised to provide innovative methodologies and integrated tools for data collection of key environmental parameters translated into preventive conservation strategies, including accessible information such as climatologic maps of ocean conditions to assess risks, to better prepare and effectively manage underwater and coastal cultural heritage.

3. Copernicus capabilities for cultural heritage in the THETIDA project

3.1 General Observations

At EU level, the comprehensive and open access data provided by the Copernicus Services has enabled a plethora of applications addressing, among others, cultural heritage. Despite the absence of a dedicated service, the high temporal and spatial resolution of the Sentinels are valuable for short-term cultural heritage monitoring, while coupled with, for instance, ENVISAT, data can reveal useful information on the long-term evolution of a heritage site and its surroundings. Cultural heritage evaluations and preservation strategies can benefit from most of the Copernicus Services, such as the Copernicus Land Monitoring Service (CLMS) providing land use and changes, ground motions detections, land surface temperature and moisture monitoring. As stated within *PwC Report on Copernicus Services in Support to Cultural Heritage*, CLMS can support 3D reconstruction visualisations of endangered heritage sites, providing a 3D experience to the public, on site or online, while satellite imagery of the site serves as a basis for the 3D elevation model of the site [13]. The Copernicus Atmosphere Monitoring Service (CAMS) supports with information on insolation monitoring, a key factor in the

ageing of built structures, in addition, information on the chemical composition of the atmosphere helps identify areas where historical buildings are more likely to deteriorate. Furthermore, the Copernicus Climate Change Service (C3S), and the Copernicus Emergency Management Service (Copernicus EMS) respectively enable to assess the frequency as well as the damages caused by natural hazards, the historical datasets allow for the creation of detailed vulnerability maps necessary to efficiently prepare conservation strategies based on risks assessment, and real-time monitoring of emergency events such as fires and flash floods. For THETIDA's purposes, the ocean modelling and forecasting provided by Copernicus Marine Environment Monitoring Service (CMEMS) are of crucial relevance to evaluate the risks faced by underwater and coastal cultural heritage sites [14].

It offers insights into wind intensity and current velocity, supporting, among others, the planning of diving activities; it is complemented with near-real time in-situ monitoring of local sea surface height and sea level anomalies in European regional seas [15]. Combined with the temporal series available for instance within C3S, it enables monitoring and mapping of coastal deformation. Both Copernicus Services thus provide a comprehensive data set to inform local communities on multiple aspects related to the status of their natural, underwater, and coastal cultural heritage. CLMS is also widely used for the identification of previously searched sites in a dedicated area, for photogrammetric mapping, elevation modelling, or vegetation level monitoring to plan efficient conservation and preparedness strategies. The diversity of Copernicus services and products applicable to THETIDA's research and development activities eloquently shows the variety of data needed to effectively monitor and safeguard cultural heritage.

3.2 THETIDA Best Practices

THETIDA uses geospatial data to develop innovative services, including long-term mapping of coastline changes and coastal erosion, relative coastal deformation and inundation prediction, changes in permafrost thawing dynamics, flood and landslide maps, maps of the biophysical material degradation, 3D documentation of underwater and coastal cultural heritage sites, land use/cover change maps, as well as to monitor the water quality of aquaculture areas and river estuaries. These services require the creation of state-of-the-art algorithms, processing satellite and other remote sensing data acquired by Unmanned Aerial Vehicles (UAVs) and Autonomous Underwater Vehicles (AUVs) or Remotely Operated Vehicles (ROVs).

The outcomes of the data collection, processing, and modelling approaches developed by the project partners will leverage and enhance existing Copernicus Services'

products. For instance, CMEMS forecast and reanalysis data is being used to develop high-resolution models that evaluate the impact of ocean variables on UCH. Additionally, advanced climatological and geo-hazard maps, based on Copernicus Services enhanced via consensus models, will be developed for the seven THETIDA pilot sites to reflect the end-users' specific needs in adaptation and mitigation of natural and climate-induced disasters.

THETIDA will play a key role in tailoring existing Copernicus Services to non-traditional Copernicus end-users from the cultural heritage and climate monitoring sectors.

4. THETIDA methodological innovation for participatory risk assessment and climate adaptation strategies: the Living Labs

THETIDA project is set to play a significant role in tackling cultural heritage vulnerability to natural hazards and the effects of climate change, while supporting a bottom-up approach to policymaking integrating technically and scientifically accurate data, as well as actual needs of the reference sites' stakeholders and communities, as well as bolstering citizen involvement through participatory tools (such as LLs).

The core innovation of THETIDA relies on the combination of highly performant data collection and analysis methods, through cutting-edge technologies, with intuitive and user-friendly information and data sharing through participatory processes and citizen engagement. By combining a users-centred approach through the LL and citizen science, to open innovation and stakeholder/community engagement, the project enables local communities to contribute to data collection, and to share their views, experiences, needs, and expectations concerning the heritage sites. To enhance communities' participation and engagement, the THETIDA project has implemented LLs in all its pilot sites. Taking place in two distinct phases, labelled as dialogue and co-creation, the LLs function as interaction spaces in which stakeholders including local administrators, researchers and experts, industry representatives, students, and citizens exchange information, assess the value of the sites, share their experience, knowledge, and state the sites' preservation needs, as well as their requirements as site actors.

The direct connections created among and between stakeholders and the sites can therefore support the transformation of current top-down management practices into more sustainable ones, involving a diverse set of committed individuals at different levels. Such personal and cultural ties tend to ensure medium to long-term commitment to the risk monitoring and conservation of the sites.

One of the assets of the project is to systematically apply diverse citizen engagement methods to connect different stakeholders to existing knowledge and data. The direct involvement of local communities in the management of the cultural heritage sites facilitates a tailored approach to meet the needs of the sites. The transversal and multi-disciplinary approach allows to attain European priorities while increasing public awareness about the specific vulnerability of selected cultural heritage sites and the need to sustainably plan climate adaptation strategies at the local level. The project hence contributes to and demonstrates European technical and scientific expertise by complementing research on underwater and coastal cultural heritage, climate change adaptation and mitigation, satellite applications, participatory processes, and citizen science, among others.

In the coming months, Living Labs activities will be conducted in the seven THETIDA pilot sites to establish the social value and assess the impact of the sites to and with stakeholders, such as local authorities and heritage operators. The contribution of the heritage sites to society and wider local economy, the threats they face, and their perceived vulnerabilities, will be expressed and detailed by selected actors. In a second stage, following the LLs methodology developed in the project, the sites will be looked at in terms of risk monitoring and sustainable management. Through participatory mapping, local communities will be able to co-create future scenarios and roadmaps on the site. To support awareness raising and visualisation, tools such as design charettes and the THETIDA mobile app will be used.



Fig. 1. Living Lab conducted in Italy in June 2024.

5. A crowdsourcing tool: the THETIDA mobile app

The THETIDA mobile application, which will be used as a portal to guarantee access to reliable and up-to-date data, and to collect first-hand information through citizen participation, is one of the tools available to local stakeholders participating in the LLs. It is a user-friendly tool for end-users to visualise 3D representations of

THETIDA pilot sites, and to witness live the impact of natural hazards, extreme weather events, or other climate-related threats on the sites. The use of Augmented Reality (AR) makes of the THETIDA mobile application a powerful tool to visualise the vulnerabilities of the site and the impacts of climate change and natural hazards [16]. The visual representations, combined with the critical exchange of information facilitated by LLs, should play an important 'awakening' role among the variety of stakeholders, increasing knowledge and awareness to strengthen engagement to develop adequate sustainable conservation strategies.



Fig. 2. Screenshot of the THETIDA mobile app with an AR visualisation of the Equa shipwreck.

By making local communities aware of the vulnerability of cultural heritage, LLs and their tools stimulate discussion on climate change and its environmental impacts, and on ways to adapt to these changes and prevent their deterioration. It has been recognised by the European Commission that "heritage can be used as a [powerful] vehicle to communicate information on climate change and all its consequences for European societies" [17]. As such, discussion can be seen as the first step towards adaptation.

6. Conclusions

Through its holistic and comprehensive approach of cultural heritage, THETIDA represents a step towards the integration of cultural heritage within relevant policy areas (disaster risk management, climate change adaptation, urban planning and development, etc.) and illustrates the role that cultural heritage can play in

supporting non-cultural sectors, such as the space or the green sector.

With the direct participation of stakeholders within LLs, THETIDA will gain invaluable understanding of needs, data for Europe's underwater and coastal cultural heritage to ensure the devise of sustainable adaptation plans. Key input generated by project activities will enable consortium partners to validate the scientific and technical developments of the project, and to tailor progresses to actual users' requirements, for efficient management strategies and sustainable preservation of the sites.

Furthermore, the data collected through innovative sensors, the models developed, and the results of the analysis carried, will be used to enhance Copernicus Services capabilities to address the requirements of the cultural heritage sector, while reinforcing its ability to assess and monitor natural hazards and the impact of climate change on Europe's environment. The work carried out within THETIDA has been designed to facilitate the uptake of Copernicus Services by non-traditional users directly addressing their needs and requirements.

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