HERITAGE AT RISK

SPECIAL EDITION



CLIMATE CHANGE - COASTAL AND UNDERWATER CULTURAL HERITAGE AT RISK: CHALLENGES, THREATS AND SOLUTIONS

ICOMOS
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CHANGEMENT CLIMATIQUE - PATRIMOINE CULTUREL CÔTIER ET SUBAQUATIQUE EN DANGER : DÉFIS, MENACES ET SOLUTIONS

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CAMBIO CLIMÁTICO - PATRIMONIO CULTURAL COSTERO Y SUBACUÁTICO EN RIESGO: RETOS, AMENAZAS Y SOLUCIONES

EDITED BY

HAKAN ÖNIZ – LARO G. CANOURA – ANDREW VIDUKA – CHRISTOPHER J. UNDERWOOD

PUBLISHED BY

THE INTERNATIONAL COUNCIL ON MONUMENTS AND SITES

(ICOMOS)

INTERNATIONAL COMMITTEE ON THE UNDERWATER CULTURAL HERITAGE

(ICUCH)

'Climate Change - Coastal and Underwater Cultural Heritage at Risk: Challenges, Threats and Solutions'
Edited by Hakan Oniz - Laro González Canoura - Andrew Viduka - Christopher J. Underwood
Published by the International Council on Monuments and Sites (ICOMOS)
International Committee on the Underwater Cultural Heritage (ICUCH)

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International Council on Monuments and Sites (ICOMOS)
Office: 11 Rue de Séminaire de Confans, 94220 Charenton-le-Pont, Paris, France

Editorial support: layout and design Nathalie Keyrouz

© ICOMOS
ISBN 978-2-487082-34-2 [PDF]
978-2-487082-35-9 [print]

Bilir Basım Yayın San. Ve Tic. AŞ.
Ferhatpaşa Mh. Akdeniz Cad. No:49 Ataşehir-İSTANBUL
Tel: 0216 611 60 01
www.bilirbasim.com.tr

ICOMOS-ICUCH thanks AXA Sigorta for their support in printing this volume.

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Published by the International Council on Monuments and Sites (ICOMOS).

ICOMOS FOREWORD – AVANT PROPOS – PREÁMBULO

Teresa Patrício, ICOMOS President

It is ICOMOS' social, cultural and professional responsibility to raise awareness of the importance of cultural heritage and its protection. One aspect of cultural heritage that is often both out of sight and out of the mind of policy makers, is underwater cultural heritage. In 2022, ICOMOS published a Heritage at Risk volume focussing on underwater cultural heritage containing five sections: legal and policy perspectives; threats, challenges and solutions; *in situ* preservation; public engagement, and capacity building. While they remain as issues to be addressed, this volume is devoted to one overarching theme: Climate Change. While climate change is being reported almost daily in news reports describing extreme weather events from drought to sea level rise and causing major societal problems from famine through to the spread of diseases: it also threatens our built and submerged heritage.

This volume is designed to address this lack of understanding of how underwater cultural heritage is at very significant risk due to the impact of changing climate. This volume is innovative in merging articles that feature both cultural heritage perspectives with those of climate scientists, the latter incorporating data from the Intergovernmental Panel on Climate Change IPCC).

To ensure maximum exposure, this publication will be presented to policy makers during COP 31, Anatalya-Türkiye, November 2026. Subsequently, predominantly through distribution of a digital version of the volume, it will also be widely shared among experts, the wider professional community and the public. Through this process ICOMOS aims to raise general awareness of the issue and threats to underwater cultural heritage and to encourage increased documentation, preservation and protection of this important heritage. Lastly, I would like to thank the International Committee on Underwater Cultural Heritage (ICUCH) for taking the initiative to publish this special edition.

Il relève de la responsabilité sociale, culturelle et professionnelle de l'ICOMOS de sensibiliser à l'importance du patrimoine culturel et de sa préservation. Le patrimoine culturel subaquatique constitue un aspect du patrimoine culturel souvent ignoré ou oublié des décideurs politiques. En 2022, l'ICOMOS a publié un volume de la collection « Heritage at Risk » (Patrimoine en péril) consacré au patrimoine culturel subaquatique, articulé autour de cinq volets : perspectives juridiques et politiques ; menaces, défis et solutions ; conservation **in situ** ; engagement du public ; et renforcement des capacités. Bien que ces questions demeurent d'actualité, cet ouvrage se concentre sur un thème majeur : le changement climatique. Si les médias rendent compte presque quotidiennement d'événements météorologiques extrêmes — allant de la sécheresse à l'élévation du niveau de la mer — et de leurs conséquences sociétales graves, telles que la famine ou la propagation de maladies, le changement climatique menace également notre patrimoine bâti et submergé.

Cet ouvrage vise à remédier au manque de compréhension concernant les risques considérables auxquels le patrimoine culturel subaquatique est exposé en raison de l'évolution du climat. Il se distingue par une approche innovante, associant des articles traitant du patrimoine culturel à des contributions de climatologues, ces derniers intégrant des données issues des rapports du Groupe d'experts intergouvernemental sur l'évolution du climat (GIEC).

Afin d'assurer une visibilité maximale, cette publication sera présentée aux décideurs politiques lors de la COP 31, qui se tiendra à Antalya (Turquie) en novembre 2026. Par la suite, elle sera largement diffusée — principalement via une version numérique — auprès des experts, de la communauté professionnelle au sens large et du grand public. À travers cette initiative, l'ICOMOS entend sensibiliser l'opinion publique aux enjeux et aux menaces pesant sur le patrimoine culturel subaquatique, tout en encourageant une meilleure documentation, préservation et protection de ce patrimoine essentiel.

Enfin, je tiens à remercier le Comité international sur le patrimoine culturel subaquatique (ICUCH) d'avoir pris l'initiative de publier cette édition spéciale.

Es responsabilidad social, cultural y profesional de ICOMOS crear conciencia sobre la importancia del patrimonio cultural y su protección. Un aspecto del patrimonio cultural que a menudo pasa desapercibido para los responsables de la formulación de políticas es el patrimonio cultural subacuático. En 2022, ICOMOS publicó un volumen de la serie *Heritage at Risk* (Patrimonio en Peligro) centrado en el patrimonio cultural subacuático, el cual consta de cinco secciones: perspectivas jurídicas y políticas; amenazas, desafíos y soluciones; conservación **in situ** ; participación pública y desarrollo de capacidades. Si bien estas cuestiones siguen vigentes, el volumen se dedica a un tema central: el cambio climático. Aunque el cambio climático aparece casi a diario en las noticias —describiendo fenómenos meteorológicos extremos que van desde sequías hasta el aumento del nivel del mar, y provocando graves problemas sociales que abarcan desde hambrunas hasta la propagación de enfermedades—, también amenaza nuestro patrimonio construido y sumergido.

Este volumen tiene como objetivo abordar el desconocimiento sobre el riesgo significativo que corre el patrimonio cultural subacuático debido al impacto del cambio climático. La obra es innovadora al combinar artículos que presentan perspectivas del ámbito del patrimonio cultural con las de científicos climáticos; estos últimos incorporan datos del Grupo Intergubernamental de Expertos sobre el Cambio Climático (IPCC).

Para garantizar la máxima difusión, esta publicación se presentará a los responsables de políticas durante la COP 31, que se celebrará en Antalya (Turquía) en noviembre de 2026. Posteriormente, y principalmente mediante la distribución de una versión digital, se compartirá ampliamente entre expertos, la comunidad profesional en general y el público. A través de este proceso, ICOMOS busca sensibilizar a la opinión pública sobre esta problemática y las amenazas que enfrenta el patrimonio cultural subacuático, así como fomentar una mayor documentación, conservación y protección de este importante patrimonio.
Por último, deseo agradecer al Comité Internacional sobre Patrimonio Cultural Subacuático (ICUCH) por tomar la iniciativa de publicar esta edición especial.

Teresa Patrício,
ICOMOS President.



ABOUT ICOMOS

ICOMOS, the International Council on Monuments and Sites, is a non-governmental organisation working to conserve and protect cultural heritage sites around the world. We are the only worldwide NGO dedicated to applying scientific techniques, theories and methodology to the conservation of both tangible and intangible elements of cultural heritage places.

We are a global network of professionals and experts working together. As a diverse membership network covering the whole range of heritage specialisms,

ICOMOS' strength and impact comes from our ongoing interdisciplinary exchanges and conversations, which inform all its approaches and activities.

ICOMOS' members work together to improve the preservation of our cultural heritage. This means that we are constantly reviewing and improving standards and techniques specific to each type of cultural heritage: monuments, buildings, groups of buildings, sites, places, and landscapes.

ICOMOS
international council on monuments and sites

ABOUT ICUCH

The International Committee on the Underwater Cultural Heritage (ICUCH) is an ICOMOS Scientific Committee founded in 1991 to promote international cooperation in the protection and management of underwater cultural heritage (UCH) and advise ICOMOS[1] on issues related to UCH, globally.

The committee comprises international expert members with experience in heritage management, conservation, archaeology, and maritime law spanning the five geographical regions as defined by UNESCO: Africa + Arab States, Asia and Pacific, Europe and North America, and Latin America and Caribbean.

ICUCH's first mandate was the creation of the Charter on the Protection and Management of Underwater Cultural Heritage, adopted by ICOMOS in Sofia,1996. The Charter laid the foundations of the Annex Rules to the Convention on the Protection of the Underwater Cultural Heritage (UNESCO 2001).

ICUCH is mandated to: promote sound ethical management of underwater cultural heritage where *in situ* preservation is the first option; support scientific research, including both disturbance and non-disturbance activities; encourage public presentation of underwater cultural heritage and public participation in underwater cultural heritage; promote the 1996 ICOMOS Charter and the 2001 UNESCO Convention's Annex as best practice guidance regarding underwater cultural heritage; assist stakeholders in the field of maritime archaeology to manage, protect, carry out sound study, and share knowledge on underwater cultural heritage; raise the profile and increase public awareness of the existence and value of the world's underwater cultural heritage; promote ethical activities on and with underwater cultural heritage through facilitating development of national and regional cooperation, programs and legislation; encourage an inclusive approach to underwater cultural heritage; support, initiate and/or assist in education and capacity-building initiatives in respect of the management, research, protection, conservation and dissemination of underwater cultural heritage; provide a forum for discussion and for the exchange of information, regionally and internationally, on matters of principle and of technical, legal and administrative practice affecting underwater cultural heritage; provide information for governments, the general public and political organizations about the protection and preservation of underwater cultural heritage; support and encourage the gathering and sharing of diverse professional experience and knowledge and the development of guidance for ICOMOS on underwater cultural heritage, taking into account cultural diversity and sensitivities and in cooperation with other ICOMOS Scientific and National Committees; and assist Associate Members and emerging professionals in developing their specialisation and competence in underwater cultural heritage; raise the profile and increase public awareness of the existence and value of the world's UCH; promote ethical practices on and with UCH through facilitating development and regional co-operation, programs and legislation; encourage an inclusive approach to UCH; support, initiate and/or assist in education and capacity building initiatives, research, protection, conservation and dissemination of UCH and provide information for governments, the general public and political organisations about the protection and preservation of UCH.

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INTRODUCTION TO CLIMATE CHANGE - COASTAL AND UNDERWATER CULTURAL HERITAGE AT RISK: CHALLENGES, THREATS AND SOLUTIONS

Laro Gonzalez Canoura and Andrew Viduka

Coastal and underwater cultural heritage is the tangible evidence of how people have lived with, used, shaped and responded to changing environments over millennia. Along coasts and underwater there are archaeological sites, stone tidal weirs, historic ports and harbours, shipwrecks, aircraft, submerged landscapes, historic structures, cultural seascapes and many other traces of past human activity. They represent not only archaeological and historical evidence, but also places of memory, identity and connection between communities and their environments.

These places are now themselves experiencing a rapidly changing climate.

Sea-level rise, coastal erosion, flooding, changing storm patterns, increasing temperatures, changes in precipitation and groundwater, ocean warming and acidification, increased turbidity, changing sediment regimes and biological changes can all affect underwater cultural heritage and or coastal heritage. In many locations, these pressures interact with existing human pressures, including coastal development, pollution, tourism, infrastructure, dredging and changes in land and marine use. The result is not a single, uniform climate threat to cultural heritage, but a complex and changing set of risks whose consequences vary greatly from one place to another.

For policy-makers concerned with climate change, the question is therefore not simply whether cultural heritage is at risk. It is how that risk should be understood, prioritised and addressed, and how cultural heritage can be incorporated into wider strategies for climate adaptation and resilient coastal development.

This book brings together 27 contributions featuring different disciplinary, professional and geographical perspectives. The volume is not intended to provide an exhaustive global inventory. Instead, the selection seeks to demonstrate the breadth, variability and or commonalities of the challenges encountered across coastal and underwater cultural heritage.

Cultural heritage and risk

The climate science underpinning this volume is not in question. The assessments of the Intergovernmental Panel on Climate Change (IPCC), together with regional and local climate projections and downscaling, provide an increasingly detailed understanding of how climate hazards are changing and are expected to change. What is less well developed is the translation of this knowledge into an understanding of what those changes mean for specific cultural heritage places, materials and values.

It is useful to think about climate change and cultural heritage through a simple sequence:

hazard → exposure → vulnerability → impact → risk → response

However, many contributions to this volume highlight a basic lack of information about the coastal and underwater cultural heritage assemblages, proving insufficient to make informed decisions.

Climate change can alter the intensity, frequency or duration of hazards. Heritage is exposed to those hazards according to its location and environmental setting. Its vulnerability depends on its physical characteristics, condition, past alterations, surrounding environment and other factors. Impacts may affect the physical fabric of a site, disturbing archaeological context, cultural values, community relationships or the possibility of future research. Risk therefore cannot be inferred from climate projections alone.

A global or regional projection of sea-level rise, for example, does not in itself tell us what will happen to a particular archaeological site. The consequences depend on its elevation, geomorphological setting, sedimentary environment, construction materials, state of preservation, groundwater conditions, exposure to waves and storms, and many other factors. As pointed out in several papers in this volume, sea level rise may be offset in some instances by tectonic uplift. As such, the same climate hazard can therefore produce very

different outcomes at different sites. Conversely, a site may be affected simultaneously by several hazards, with their combined effects being greater—or simply different from—their individual effects.

This distinction between climate hazard and heritage impact is fundamental. Climate change provides the forcing, but exposure, vulnerability, significance and local environmental conditions determine how that forcing is experienced by cultural heritage. Understanding climate risk to cultural heritage is consequently an inherently interdisciplinary task.

The contributions in this volume nevertheless share an important foundation: an engagement with the rapidly expanding body of climate knowledge generated through the IPCC and through regional and local climate studies. In different ways, the authors consider how broad climate projections and locally specific information can be connected to the realities of cultural heritage management in their locales. The resulting picture is necessarily incomplete, but it is also revealing. The differences between places and types of heritage are as important as the common threats.

Solutions?

The title of this volume includes the word solutions, but it is important to be clear about what that means. There are already many examples of effective monitoring, documentation, conservation, risk assessment, adaptation and community engagement. There are also approaches that can reduce exposure or vulnerability, and in some circumstances physical protection may be appropriate. In other situations, however, intervention through excavation, when not impractical and unaffordable, may be the only response to document before destruction. There is no universal technical solution.

More importantly, in many cases we do not yet know enough to determine which response will be most appropriate. Consequently, uncertainty is not simply a characteristic of climate projections. It is also a characteristic of our knowledge of cultural heritage and of the effectiveness of possible responses.

This has two implications. First, uncertainty should not become a justification for inaction. Second, uncertainty means that considerably more research and resources are needed now. The solutions to climate risks for cultural heritage therefore cannot be understood simply as a list of technologies or interventions. They also include building the knowledge and institutional capacity required to make better decisions. In this sense, research is itself an adaptation measure.

For these reasons, coastal and underwater cultural heritage should not be treated as a specialist issue separate from mainstream climate policy. Heritage is part of the built and natural environment in which adaptation decisions are already being made. It intersects with coastal planning, disaster risk reduction, infrastructure investment, tourism, ecosystem management, community resilience and sustainable development. Climate adaptation strategies should consider potentially impacted cultural heritage from the outset rather than only after major infrastructure, coastal or environmental decisions have been made. Conversely, heritage management needs to engage more directly with climate projections, adaptation planning and the wider policy processes that will shape future coastal environments.

A global challenge

The structure of this volume reflects its purpose. The book begins with three contributions that address thematic or conceptual questions. These provide broader perspectives through which to consider the challenges that follow. The remaining contributions then move geographically westwards from the COP31 host country, Türkiye.

This is not intended as a classification of the world's coastal and underwater heritage, nor does the geographical sequence imply that one region is more or less vulnerable than another. Rather, the progression provides a journey through different environments, histories, heritage types and climate challenges.

Starting from Türkiye is particularly appropriate in the context of COP31. Türkiye sits at the intersection of several seas and cultural regions and has an exceptionally rich coastal and underwater heritage. From this starting point, the contributions move westwards, encountering different combinations of climate hazards, environmental processes, heritage characteristics, institutional contexts and approaches to management.

The geographical sequence therefore reinforces one of the principal arguments of the volume: there is no single global experience of climate change and cultural heritage.

Looking ahead

The heritage presented in this volume represents only a fraction of the coastal and underwater cultural heritage affected by climate change. The 27 contributions cannot provide an exhaustive assessment of the problem, nor do they seek to do so. Their purpose is to make visible the range of challenges, perspectives and uncertainties that need to be considered.

What emerges is both a warning and an opportunity. The warning is that climate change is already altering the environmental conditions on which the preservation of cultural heritage depends. Some impacts will be gradual; others will be sudden. Some will be detectable only through sustained monitoring and research. In some cases, loss may ultimately be unavoidable.

The opportunity is to improve how decisions are made before that loss occurs. Doing so requires cultural heritage to be incorporated more fully into climate-risk assessment and adaptation planning. It requires better connections between global climate knowledge, regional projections and local observations. It requires sustained research, monitoring and documentation. It requires resources and institutional capacity. And it requires acceptance that effective adaptation may involve difficult choices rather than universally applicable solutions.

Above all, it requires recognising that knowledge is a prerequisite for action, but knowledge itself requires investment.

The contributions that follow demonstrate what can be learned when different disciplines, places and experiences are brought together. They also reveal how much remains unknown. For policy-makers meeting at COP31, this should not be understood as a reason to defer action. Rather, it is an argument for integrating cultural heritage into climate policy now while simultaneously investing in the research, monitoring, expertise and resources needed to improve future decisions.

Coastal and underwater cultural heritage is the product of thousands of years of human interaction with changing environments. Its future will likewise depend on how effectively societies understand and respond to environmental change. Protecting that heritage is therefore not simply about preserving the past. It is part of deciding what knowledge, places, identities and connections we choose to carry into the future.

CONTENTS

PREFACE

ICOMOS FOREWORD

Teresa Patrício, ICOMOS President 5

ABOUT ICOMOS 7

ABOUT ICUCH 8

INTRODUCTION TO CLIMATE CHANGE - COASTAL AND UNDERWATER CULTURAL HERITAGE AT RISK: CHALLENGES, THREATS AND SOLUTIONS

Laro Gonzalez Canoura, and Andrew Viduka 9

THEMATIC THREATS

THE PRESENT AND FUTURE IMPACTS CLIMATE CHANGE HAZARDS ON COASTAL AND UNDERWATER HERITAGE

Julius John Dimabayao, Laro González Canoura, and Javier L. Lara 16

WHEN HOMES BECOME EMERGENT UNDERWATER CULTURAL HERITAGE

Elena Perez-Alvaro, Carlota Pérez-Reverte, Verónica Walker Vadillo, and Emilia Mataix Ferrándiz 21

HOW CLIMATE CHANGE IS RESHAPING UNDERWATER ARCHAEOLOGY: FROM EXPLORATION TO PRESERVATION

Laro G, Canoura, Mauro Frontini Miguel, and Javier L. Lara 27

CASE STUDIES

CLIMATE CHANGE AND CULTURAL HERITAGE IN THE EASTERN MEDITERRANEAN AND BLACK SEA

Hakan Öniz, and Ceyda Öztosun 36

CLIMATE-RELATED THREATS TO ARCHAEOLOGICAL SITES ALONG THE BULGARIAN BLACK SEA COAST

Nayden Prahov 46

CLIMATE-RELATED RISKS TO UNDERWATER AND RIVERINE ARCHAEOLOGICAL HERITAGE ALONG THE LOWER DANUBE
Aleta Guadelli, and Nayden Prahov **51**

DIGITAL TECHNOLOGIES FOR PROTECTING MONTENEGRO'S UNDERWATER CULTURAL HERITAGE FROM CLIMATE THREATS
Darko Kovačević **57**

RIVERINE HERITAGE IN THE CHANGING ENVIRONMENT OF THE MIDDLE DANUBE BASIN, HUNGARY
Attila J. Tóth **64**

PROTECTION OF UNDERWATER CULTURAL HERITAGE IN CROATIA
Mladen Pešić **70**

CLIMATE CHANGE AND CULTURAL HERITAGE: IDENTIFYING AND MONITORING EMERGING CHALLENGES IN COASTAL AND UNDERWATER HERITAGE (ITALY)
Castagnino Berlinghieri E.F, Monaco C., and Antonioli F. **75**

CLIMATE CHANGE AND ITALIAN UNDERWATER CULTURAL HERITAGE: THE GRADO 6 AND LAZISE SHIPWRECKS AS CONTRASTING CASE STUDIES
Massimo Capulli **80**

OPERATIONALIZING A NOVEL CLIMATE CHANGE RISK ASSESSMENT FRAMEWORK ON NORWEGIAN COASTAL STONE AGE: THE VINGEN ROCK ART CASE STUDY
Julius John Dimabayao, Laro González Canoura, and Javier L. Lara **88**

SUBNORDICA: THE CHALLENGES OF ETHICAL, NET ZERO DEVELOPMENT OF THE WORLD'S COASTAL SHELVES
Katrine Juul Andresen, Peter Moe Astrup, Vincent Gaffney, and Svea Mahlstedt **94**

COASTAL EROSION AND ITS IMPACT ON ARCHAEOLOGICAL HERITAGE: CASE STUDY OF TIPAZA (ALGERIA)
Rafik khellaf **102**

THE LAST GREAT WILDERNESS: UNDERWATER CULTURAL HERITAGE AND CLIMATE CHANGE IN THE ANTARCTIC
Dragomir Garbov **106**

CLIMATE CHANGE IMPACTS ON UNDERWATER CULTURAL HERITAGE IN NORTHERN PATAGONIA, ARGENTINA: QUANTIFYING ENVIRONMENTAL RISKS FOR DATA-DRIVEN MANAGEMENT
Alessandra Bonazza, Alessandro Sardella, Virna L. Meccia, Mónica Grosso, Julieta Frère, and Dolores Elkin **114**

RISING SEAS, LOCAL SOLUTIONS: CLIMATE CHANGE AND THE FORTIFIED MARITIME CULTURAL LANDSCAPE OF CARTAGENA DE INDIAS (COLOMBIA)
Carlos Del Cairo Hurtado, Jesús Aldana Mendoza, Gabriela Caro León, Victoria Báez Santos, Carla Riera Andreu, Liliana Rozo Pinzón, Juan David Sarmiento Rodríguez, and Juliana Quintero Hernández **121**

CLIMATE CHANGE AND THE PRESERVATION OF FRESHWATER SHIPWRECKS – LAKE CHAMPLAIN AS CASE STUDY
Carolyn Kennedy, and Liz Trevino **129**

AT THE WATER'S EDGE: CLIMATE CHANGE AND COASTAL AND UNDERWATER CULTURAL HERITAGE IN THE PACIFIC
Ania M. Kotarba-Morley **135**

CLIMATE CHANGE AND THREATS TO COASTAL AND UNDERWATER CULTURAL HERITAGE IN NEW ZEALAND
Kurt Bennett, and Matthew Campbell **140**

HIDDEN HERITAGE IN A SILENT WORLD - THE POTENTIAL IMPACTS OF CLIMATE CHANGE ON HISTORIC UNDERWATER CULTURAL HERITAGE IN AUSTRALIA'S GREAT BARRIER REEF MARINE PARK
Andrew Viduka, and Martin Gibbs **144**

UNCERTAIN FUTURE OF THE UNDERWATER CULTURAL HERITAGE OF STONE TIDAL WEIRS
Akifumi Iwabuchi **150**

CLIMATE CHANGE RISKS TO MACAO'S COASTAL CULTURAL HERITAGE
Zhehao Zhao **155**

MANAGING DECAY ON AN ICE-BOUND FRONTIER: POTENTIAL CLIMATE CHANGE IMPACTS ON THE UNDERWATER CULTURAL HERITAGE OF HEARD ISLAND
Dragomir Garbov, and Liam Norris **160**

CLIMATE CHANGE RISKS TO COASTAL AND UNDERWATER CULTURAL HERITAGE IN PAKISTAN
Amer Bazl Khan **167**

CLIMATE CHANGE, SEVERE WEATHER, AND UNDERWATER CULTURAL HERITAGE IN THE GULF OF OMAN: LESSONS FROM THE WORLD HERITAGE SITE OF QALHAT
Emad Khalil **173**

ENVIRONMENTAL CHANGE AND UNDERWATER CULTURAL HERITAGE IN WAR-AFFECTED UKRAINE: CHALLENGES FOR HERITAGE MANAGEMENT
Dmytro Kobaliia, and Mykhailo Mulenko **179**

APPENDICES

APPENDIX I: ICOMOS CHARTER ON THE PROTECTION AND MANAGEMENT OF UNDERWATER CULTURAL HERITAGE (SOFIA 1996) **186**

APPENDIX II: UNESCO CONVENTION ON THE PROTECTION OF THE UNDERWATER CULTURAL HERITAGE (PARIS 2001) **190**

THEMATIC THREATS



Photo Credit: GIRT Scientific Diver trainees monitoring the debris field of HMS Sirius (1790) at Norfolk Island, Australia. Photo: Andrew Viduka.

The Present and Future Impacts Climate Change Hazards on Coastal and Underwater Heritage

Julius John Dimabayao, Laro González Canoura, and *Javier L. Lara*

Introduction

The world's coastlines have long been centers of migration, settlement, subsistence, and resource exploitation, leaving a rich tangible and intangible archaeological heritage record across coastal, intertidal, and submerged environments. Today however, archaeological sites in coastal areas and those sites underwater face increasing environmental pressures. Accelerated coastal processes driven by climate change, including sea-level rise, intensified coastal flooding, cliff failures, saltwater intrusion, and changes in sea surface temperature and chemistry, threaten their long-term preservation. Many sites that were once inland now lie within reach of higher tides and increased wave action, and others are at risk of being lost to erosion or becoming submerged, completely. Yet, these processes are not entirely new. Coastal and underwater archaeological sites are located within environments that are inherently dynamic, where erosion, sediment transport, flooding, chemical alteration and biological processes have always affected preservation. Anthropogenic climate change is increasingly modifying the magnitude, frequency, duration and spatial extent of these processes. Therefore, this work synthesizes the present and projected impacts of major climate-related hazards on coastal and underwater archaeological heritage, focusing on the processes linking climate drivers to archaeological impacts.

From Environmental Processes to Climate Change-related Hazards

Understanding any climate change-related hazard requires distinguishing between environmental processes that have long shaped archaeological sites, and the ways in which anthropogenic climate change is modifying them (**Fig. 1**). Therefore, it is necessary to identify the relevant baseline formation processes and determine which of these have long existed and interacted with the archaeological record. Thereafter, knowing how these processes are modified requires that we understand how climate change acts as an altering agent (climate driver) and what measurable components can represent these changes (climate indicator). It also requires that we identify what archaeological element is exposed to these processes (archaeological receptor) and how these elements would respond to these processes (potential impact). Only then would these processes be identified as climate change-related hazards if they are deemed detrimental and pose significant impact and damage to heritage sites and objects.

Present and Future Hazard Outlook

Contemporary observations and climate projections indicate that many of these coastal and marine-related processes that shape coastal environments in the Holocene are accelerating due to anthropogenic climate change (Ruddiman *et al*., 2015), which present substantial impacts on coastal cultural and archaeological sites.

Sea level rise (SLR), storm intensification, and shifting wave regimes threaten to submerge or wash out coastal archaeological locations such as those situated on estuarine margins or raised terraces (Fenger-Nielsen *et al*., 2020). In particular, SLR is a chronic process that can be a hazard to archaeological sites and their state of preservation, as it facilitates access by other acute coastal

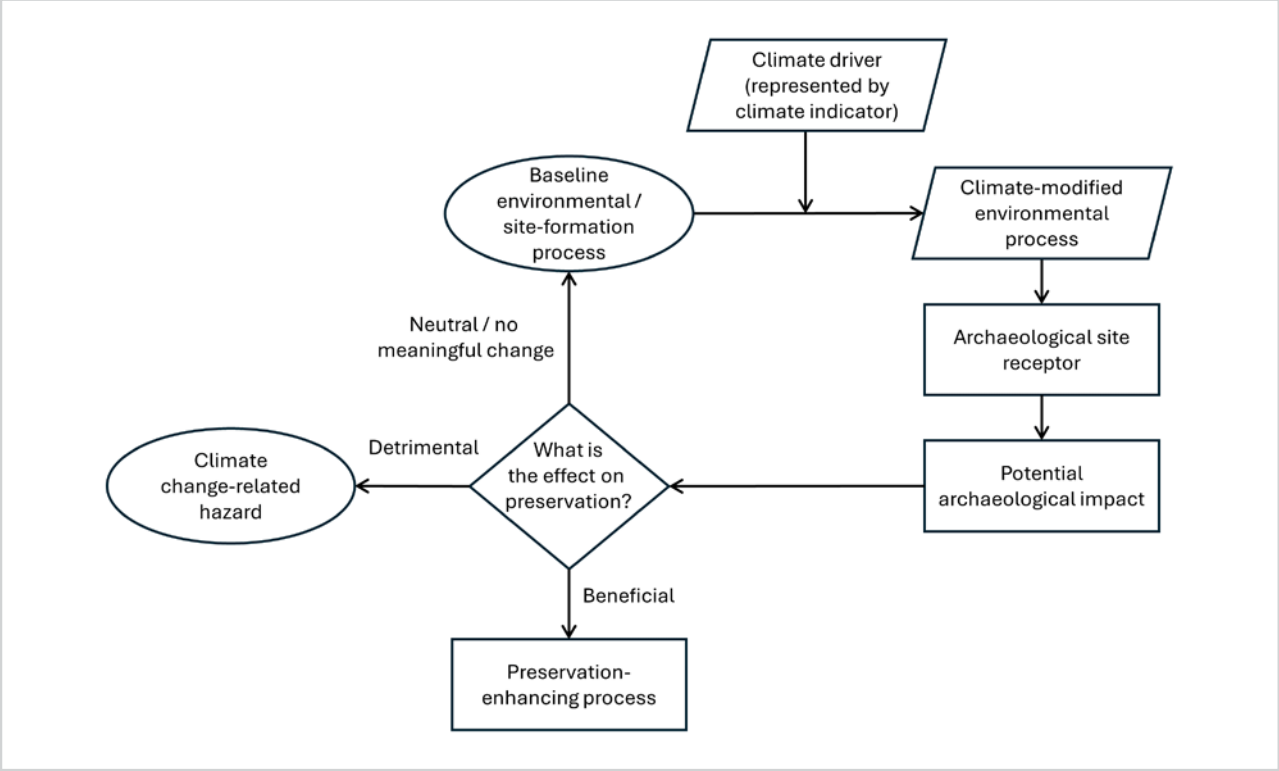


Figure 1- Vingen rock art, showing some motifs from the panel in the Hardbakken ridge. Reproduced with permission from The University Museum of Bergen.

hazards such as coastal flooding, storm-surge, and cliff retreat (Gregory *et al*., 2022) through increased material exposure. Relative to the 1995-2014 reference period, the global mean sea level is projected to rise 0.33-0.62 m under low emissions SSP1-2.6 scenario, and 0.63-1.01 m under the very high emissions SSP5-8.5 scenario by the year 2100 (IPCC, 2021).

However, global mean SLR is not uniform throughout. Regional variation is also dependent on local tectonic, geomorphic, and oceanographic processes that influence the relative sea level. For example, uneven land uplift due to isostatic rebound moderates relative SLR along the Scandinavian coast (Richter *et al*., 2012). In contrast, low-lying Mediterranean heritage sites may experience severe local impacts, with projecting substantial increases in coastal flooding and erosion risk under high-end SLR scenarios (Reimann *et al*., 2018).

Elsewhere, particularly along low-lying coasts characterized by soft sediments and archaeologically-rich stratigraphy, the loss of protective salt-marsh buffers exposes potential archaeological deposits to direct marine erosion. For example, prehistoric shell-midden strata previously sealed beneath marsh sediments become eroded once these environments are drowned by rising seas, a process commonly referred to as coastal squeezing (Murphy *et al*., 2009).

Additionally, warmer ocean temperatures and the growing incidence of marine heatwaves are reshaping regional storm dynamics and wave climate (Chen, 2024). Similarly, changes in ocean chemistry are also a concern. By the end of the century under a worst case scenario, global projections of sea surface temperatures will increase by +3.47 ± 0.78 °C; seawater will become more acidic (pH to decrease by -0.44 ±0.005), and will contain less dissolved oxygen (decrease by -13.27 ± 5.28 mmol/m3) (Kwiatkowski *et al*., 2020). These compounding physical and chemical changes increase reaction rates for carbonate-based material dissolution and biological colonization, aggravating the deterioration of submerged cultural materials (Esteban-Cantillo *et al*., 2024). Meanwhile, enhanced stratification and reduced vertical mixing of water columns is attributed to reduced oxygen levels from warming seas, which may lead to hypoxia. In certain cases, this could become beneficial to the preservation of organic heritage artefacts because of decreased microbial

activity that limits their decay (Gregory *et al*., 2022).

Moreover, in the seabed, sedimentary reworking and scouring pose additional risks to buried or submerged archaeological sites. Continuous wave-induced shear stress and ocean currents, amplified by storm events, could cause sediment disturbance in the seabed, which leads to erosion that can expose and cause irreparable damage to underwater heritage materials (Germinario *et al*., 2026).

Gaps and Implications

Understanding environmental hazards relevant to coastal archaeological sites is helpful for the fields of climate science and archaeology to move beyond a single hazard perspective to a more integrated picture of how climate processes overlap and interact through time. Coastal archaeological sites are part of these dynamic landscapes and are continuously shaped by hazards that operate in the short-term and long-term time scales. Together, these hazards introduce complex and non-linear impacts on archaeological heritage that challenge conventional approaches to risk assessment and adaptation.

A key conclusion is that many of the most damaging impacts of hazards on archaeological sites do not arise from single hazards operating in isolation, but through interconnected processes that may magnify one another's effects. Such compounding, cascading and/or amplifying interactions include among others coastal-atmospheric interactions, coastal-terrestrial interactions, atmosphere-biochemical processes, and marine-biochemical processes. Several studies have begun tackling the impacts and effects of compounding hazards (e.g., Zscheischler *et al*., 2020; Ghanbari *et al*., 2021), and their probability of concurrence based on future climate scenarios (e.g., Bevacqua *et al*., 2020).

This work points to several recurring trends and gaps in present approaches for evaluating environmental hazards to coastal archaeological sites. First, while SLR, storm surge and meteorological hazards are relatively well constrained, other hazards remain inadequately measured and/or understood. These include, among others, cliff and shoreline retreat rates at archaeological sites, site-specific erosion rates, biological colonization/material degradation rates under future humidity/warming levels, and also permafrost degradation impacts. Second, scientific records are uneven across regions, hazards, and timescales. For example, while climate and wave data are mostly available in global or local scales, each database differs in robustness, data granularity, and resolution. These inconsistencies complicate regional comparison and limits the precision of risk assessment that can be operationalized. Lastly, uncertainties in climate projections and downscaling remain. While global projections provide robust, large-scale trends, local-scale coastal processes (e.g., sediment transport, cliff dynamics, wave climate regimes) carry significant uncertainties at site scale. This can affect hazard analysis for archaeological sites, e.g., how quickly terrace edges will retreat, or whether sediments will bury or expose archaeological finds depending on the sediment budget.

The Way Forward

The synthesis of hazards presented carries several important implications for heritage risk assessment, adaptation planning, and long-term management of coastal archaeological sites. Accounting for multi-hazard and compounding processes is a good practice, rather than relying on practices that treat these hazards as isolated modules. Therefore, existing risk assessment frameworks could be improved by better incorporating multiple hazard interactions, aligning with IPCC in terms of concepts and assessing future conditions, and considering localized geomorphological and microclimatic data for a more precise assessment that reflect the complexity of interacting hazards with heritage and the landscape that contains it.

Likewise, improving hazard assessments leads to better risk assessments and more solution-oriented adaptation and management strategies. This can be done by moving beyond built-heritage solutions: combining preventive monitoring, considering nature-based measures, and, where loss is unavoidable, rapid documentation and data preservation. Ultimately, safeguarding coastal heritage in a changing climate demands interdisciplinary collaboration, flexible planning, and proactive decision-making to balance *in situ* conservation with the realities of accelerating rates of environmental hazards.

IHCantabria is a joint research institute of the Universidad de Cantabria and the Government of Cantabria (Spain), specialising in environmental hydraulics. Its multidisciplinary research integrates field observations, laboratory experimentation and numerical modelling to address challenges including climate change, coastal risks, marine and coastal engineering, environmental management and adaptation. With more than 200 experts and extensive participation in national and international R&D projects, IHCantabria increasingly applies its expertise in climate science, risk assessment and coastal processes to cultural heritage, developing interdisciplinary approaches to understand climate-related threats and support the adaptation, management and preservation of coastal and archaeological heritage.



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When homes become emergent underwater cultural heritage

Elena Perez-Alvaro, Carlota Pérez-Reverte, Verónica Walker Vadillo, and Emilia Mataix Ferrándiz

Introduction

Pacific leaders and communities have placed climate change at the centre of international legal and diplomatic debate. Tuvalu's digital nation project and the Vanuatu-led request for an advisory opinion before the International Court of Justice show how Pacific states have shaped that debate (Tuvalu, n.d.; International Court of Justice, 2025). International discussion has nevertheless often represented the region through images of 'sinking islands' and 'disappearing nations'. Although these descriptions have made sea-level rise visible, they can define communities primarily through their anticipated absence and obscure the histories and cultural relationships through which present threats are experienced. In the Marshall Islands, climate-related pressures affect places already shaped by nuclear testing and displacement (Genz et al., 2016; Maclellan, 2019). At Rapa Nui, flooding and wave action threaten ahu, moai and associated sites that remain part of a living cultural landscape (Paoa et al., 2025) (**Fig. 1**).

To describe these processes without presuming a predetermined future, this article develops a more precise vocabulary. Following Hau'ofa (1994), Oceania is used for an inhabited oceanic world in which islands, reefs, lagoons, routes and relationships form connected cultural space, rather than as an external geopolitical label. From this perspective, the shoreline does not necessarily separate one cultural world from another, although



Figure 1- A moai at the water's edge at Rapa Nui. Photograph: Elena Perez-Alvaro.

heritage administration commonly treats it as the boundary between terrestrial and underwater heritage. A place may therefore move between institutional categories as relations between land and water change without ceasing to be lived, remembered, used or claimed.

The article introduces emergent underwater cultural heritage to describe this mismatch between material transformation and cultural continuity. It is not a legal category, an automatic consequence of contact with water or a prediction of inevitable submergence. The term is not cause-specific, although this article examines its climate-related expression in Oceania. Emergence may be material, as water changes fabric, access or use; institutional, as heritage bodies begin to recognise a place differently; or social, as communities maintain or redefine their relationships with it. These processes do not necessarily occur together. Community authority must remain central to determining what carries value and how transformed places should be understood and treated (Waterton and Smith, 2010).

Emergent underwater cultural heritage in Oceania

Oceania shows why 'disappearance' is an inadequate starting point. Land reclamation, coastal protection and continued investment demonstrate active attempts to sustain homes, infrastructure and national life (Kench et al., 2018; Webb et al., 2023). As (**Fig. 2)** shows, adaptation is already reshaping the land–water boundary and the choices available to communities.

Living with water is not new to Oceania. In Lau Lagoon, Malaita, communities identifying as wane i asi, or 'saltwater people', have built and maintained artificial islands on the reef, organising homes, fishing and movement across a landscape that cannot be divided neatly into land and water (van der Ploeg et al., 2020). These islands are not automatically underwater cultural heritage. They show that making, inhabiting and maintaining the land–water boundary can itself be a cultural practice. As water alters the fabric, access and maintenance of these inhabited islands, homes may enter the field of underwater heritage attention without ceasing to be homes.

A comparison of selected English-language news coverage examined by the Women And Oceans Think Tank illustrates a related politics of description. Reports about Oceania repeatedly use expressions such as 'sinking', 'disappearing', 'front lines' and 'forcing villagers to relocate', constructing climate change as an approaching endpoint. Venice is described through a vocabulary of defence, resilience and continued intervention. Reuters reported that the city was 'kept dry' by a system that 'wards off' exceptional tides, while The Guardian described the search for a 'plan B' and Venice's 'next move' after MOSE prevented 154 potential floods (Reuters, 2022; Bennett, 2026). The verbs are to protect, manage and reimagine. Rising water initiates another stage of research, engineering and investment rather than confirming an already determined disappearance.

The comparison does not equate the circumstances of Venice and Oceania. It reveals a difference in the horizon of action made available. Oceanic communities have organised dwellings, mobility and livelihoods in relation to water over long histories, yet are more readily narrated towards relocation and loss. Emergent underwater cultural heritage recognises transformation without treating it as evidence that a community's future has already been decided.

Why the first century matters

The problem of translating physical transformation into legal categories has a long history. Roman jurists distinguished gradual accretion through alluvio from land exposed when a river abandoned its former bed (alveus derelictus). An island arising in a river (insula in flumine nata) could accrue to riparian landowners, whereas an island emerging in the sea was treated as res nullius and could be acquired through occupation (Gai. 2.70, 2.72; Inst. 2.1.20, 22–23). Water-driven transformations thus produced different classifications and consequences.

The relevance of these rules lies not in continuity between Roman property law and contemporary heritage law, but in the classificatory operation itself. Transformation by water carried no intrinsic legal meaning: law selected particular processes and made them consequential. A distinct version of this problem appears in the 2001 UNESCO Convention,



Figure 2- Sandbags reshape the shoreline in Tuvalu, illustrating how coastal protection is transforming the island to sustain everyday life. Photograph: Elena Perez-Alvaro.

which defines underwater cultural heritage as traces of human existence having a cultural, historical or archaeological character that have been at least partly underwater, periodically or continuously, for 100 years (UNESCO, 2001). This article uses 'first century' for the period after a place begins to be periodically or continuously underwater but before it can meet the Convention's temporal threshold.. The threshold delimits the Convention's scope; it should not determine when heritage institutions recognise change. Domestic legislation and other heritage instruments may apply earlier or employ broader definitions, although professional terminology and administrative divisions can still leave recently transformed places between terrestrial, coastal and underwater heritage records.

Heritage transformation does not begin only when a place becomes permanently submerged or satisfies a legal definition. Scholarship on landscape and maritime cultural landscapes has long challenged divisions at the shoreline (Ingold, 1993; Westerdahl, 1992; Ford, 2011). Emergent underwater cultural heritage asks how a place can become materially transformed while remaining socially present. During the first century, its fabric, access, uses and meanings may change, so the object that eventually becomes legally legible is not simply the object that first entered the water. A home may still be visited at low tide, a grave reached by boat or a harbour structure continue to organise movement after part of it has collapsed below the surface. Heritage relationships can therefore be transformed before permanent submergence, as access, customary use and the transmission of knowledge are altered (De Biasio and Fernandez Velasco, 2026).

The first century is not a waiting period in which nothing of heritage significance occurs. People may still be able to identify a place's names, uses, routes and associations, while adaptation decisions preserve, transform or sever those relationships. At Fagasā in American Samoa, coastal protection restricted access to traditional fishing areas and reduced opportunities for elders to transmit knowledge to younger fishers (Peau et al., 2022). Recognition must consider not only what enters the water, but what an intervention protects, covers, disconnects or creates.

A first-century approach should connect terrestrial, intertidal and submerged records and document fabric, use, access, environmental conditions, customary boundaries and community knowledge (Dawson et al., 2020). Underwater expertise may be required as soon as a place becomes periodically inundated, waterlogged or actively eroded, regardless of age. Communities should determine

which values and knowledge are recorded, who controls that information and whether heritage terminology is appropriate. The purpose is not to recast homes, harbours, cemeteries or places of work prematurely as archaeological sites, or reduce them to digital substitutes for places assumed to be doomed, but to bring relevant expertise to living places and widen the possibilities for continuity and adaptation.

Conclusions

The central question is not how to document Oceania before it disappears, but how to recognise transformation without mistaking it for absence. Submergence does not end cultural or political life. Places may remain named, remembered, used and claimed after their material conditions change, while new coastal defences, reclaimed land and altered routes can themselves acquire meaning. Emergent underwater cultural heritage names this unsettled present. It does not make every flooded object heritage or announce that a community's future has already been decided.

The first hundred years contain the greatest range of possibilities for understanding change and influencing what follows. Recognition should connect expertise across the shoreline, keep evidence and memory together, and strengthen community authority over transformed places. Underwater cultural heritage should not begin only when remains are left. It should recognise living relationships with places as land and water are reconfigured.

Women And Oceans Think Tank

Women and Oceans is a research-led think tank connecting ocean scholarship with policy, public debate and the lived realities of maritime communities. Led by women researchers, it examines the social, cultural, political and environmental dimensions of ocean spaces, with particular attention to heritage, gender, navigation and governance. It also works with journalists and media professionals to encourage accurate, inclusive and gender-aware reporting on oceans, risk, and coastal and island communities. Funded through Horizon Europe, the Think Tank forms part of United Nations Ocean Decade Project 81.6.

Across Oceania, changing relations between land and water are transforming culturally significant places while communities continue to use, remember and assert claims through them. This article proposes emergent underwater cultural heritage as a category of attention for places undergoing this transformation, keeping community authority and cultural continuity at its centre.



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How Climate Change Is Reshaping Underwater Archaeology: From Exploration to Preservation

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1. Introduction: Climate Change as an Operational Challenge for Coastal and Underwater Archaeology

Climate change is increasingly recognised as a major threat to coastal and underwater cultural heritage (Pérez-Alvaro, 2016; Sesana *et al*., 2021; Westley *et al*., 2023; Breen, 2025; Dimabayao *et al*., 2025). Sea-level rise, coastal erosion and changing storm regimes are accelerating the deterioration, exposure and potential loss of archaeological sites (Gregory *et al*., 2022; Germinario *et al*., 2026a, 2026b). Yet these physical impacts represent only one dimension of the challenge.

Coastal and underwater archaeological practice is inherently sensitive to environmental conditions. Repeated field experience generates practical knowledge of local environmental dynamics, establishing an operational baseline from which conditions can be anticipated and interventions adjusted to those encountered. This combination of accumulated knowledge and reactive adjustment provides an important capacity to cope with natural environmental variability.

Climate change challenges the reliability of this baseline. As environmental dynamics change, past experience becomes less representative of conditions to be encountered later. The need for reactive adjustment may therefore increase while the margin for effective adjustment decreases, reducing coping capacity and increasing the vulnerability of operations.

The problem is consequently twofold: climate change can transform the archaeological record while simultaneously affecting the capacity to investigate, document and preserve it. This chapter examines how this operational vulnerability translates into constraints on archaeological practice and how adaptation can address them.

2. From Operational Vulnerability to Operational Constraints

Operational vulnerability may translate into constraints when environmental variability exceeds existing margins of adjustment, progressively restricting the conditions under which archaeological activities can be planned, conducted and sustained (**Fig. 1**).

These constraints operate differently across the archaeological intervention cycle. Planning relies on anticipated conditions over weeks to months; fieldwork is directly conditioned by variability over days to hours; and monitoring and preservation extend across seasonal to longer timescales (UNESCO, 2001; Ministerio de Cultura, 2010; Maarleveld *et al*., 2013). Their significance also varies spatially between sites and areas of intervention, making operational constraints inherently scale- and context-dependent.

Within this framework, three interconnected dimensions can be distinguished: safety, referring to the conditions under which activities can be conducted within acceptable risk; feasibility, referring to whether archaeological methods and protocols can achieve their intended objectives; and sustainability, referring to whether these activities can be maintained within available temporal, logistical, human and financial resources (**Tab. 1**).

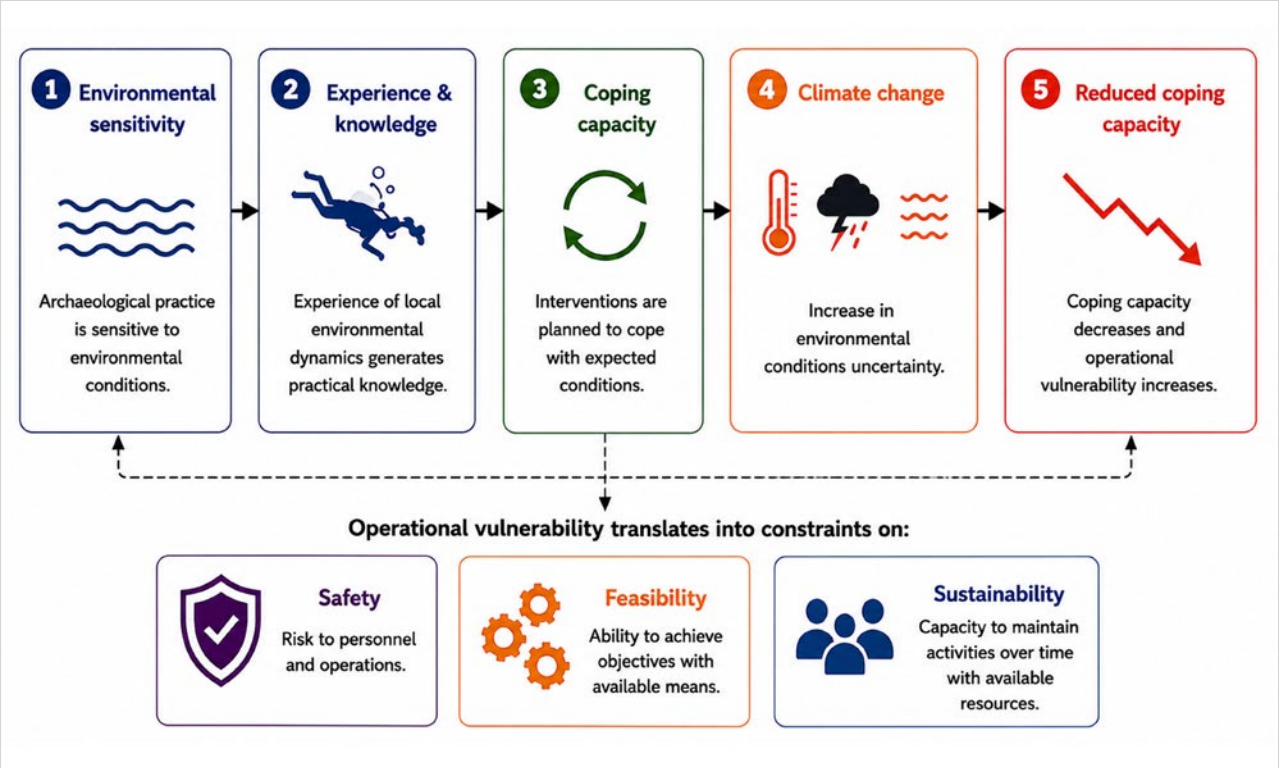


Figure 1- From environmental change to operational vulnerability. Conceptual pathway showing how climate-driven uncertainty may reduce experience-based coping capacity, increasing operational vulnerability and constraining the safety, feasibility and sustainability of coastal and underwater archaeological practice.

2.1 Operational Safety

Operational safety constitutes the first constraint. Heat stress and metocean conditions represent two major climate-sensitive controls, affecting human physiological tolerance and marine operations, respectively, among other factors such as climate-driven changes in marine ecosystems and associated biological hazards.

While there is a global increase in temperatures, these are not evenly distributed, as mid-latitude and semi-arid regions are projected to increase up to twice the Global Warming Level (IPCC, 2023; Copernicus Climate Change Service [C3S], 2026). Increasing thermal exposure can reduce physical working capacity and require shorter working periods or longer recovery times (Dasgupta *et al*., 2021; Lemke & Kjellstrom, 2012; Szewczyk *et al*., 2021). More critically, thermal conditions may increasingly reach regulatory thresholds such as ISO 7243:2017, restricting when and for how long field operations can be safely conducted.

Underwater operations are similarly constrained by waves, currents and sea state. Ocean warming has already been associated with changes in global wave power (Reguero *et al*., 2019), while extreme wave conditions are projected to change substantially but heterogeneously across regions (Lobeto *et al*., 2021). Their magnitude, frequency or timing may therefore alter the availability of suitable conditions for underwater operations.

Because acceptable thermal and metocean conditions must coincide, these changes may contract, shift or fragment operational windows previously established through accumulated field experience. This may increase adjustment or interruption during fieldwork and reduce the regularity and predictability of access required for monitoring and preservation. Additionally, ecosystem change and the appearance or increase of harmful (toxic, venomous and/or predatory) exotic species may change the risk profile of divers, requiring more stringent protection and preventative measures (Uysal & Turan, 2020).

Safety, however, represents only the first threshold. Conditions may remain safe while constraining the effectiveness of archaeological methods and techniques.

Dimension	Operational question	Climate-sensitive controls	Archaeological consequence
Safety	*Can the intervention be conducted safely?*	*Heat stress; waves; currents; sea state*	*Contracted, shifted or fragmented operational windows*
Feasibility	*Can methods achieve their intended objectives?*	*Sediment dynamics; visibility; currents; biological coverage*	*Method adjustment/combination; reduced repeatability and comparability*
Sustainability	*Can the intervention be maintained with available resources?*	*Consequences of maintaining safety and feasibility*	*Increased time, personnel, logistics, equipment and financial requirements*

Table 1- Operational constraints on archaeological practice. Summary of the safety, feasibility and sustainability dimensions through which climate change may constrain coastal and underwater archaeology.

2.2 Operational Feasibility

Operational feasibility constitutes the second constraint. Coastal and underwater archaeology increasingly relies on non-invasive techniques, including drone and robotic surveys, photogrammetry and marine geophysics, whose effectiveness depends on the conditions under which archaeological evidence can be detected and documented (Diamanti & Ødegård, 2024; Remondino, 2011).

Climate-driven changes in erosion, deposition and sediment mobilisation can alter the exposure and surface expression of archaeological evidence (Toimil *et al*., 2020; Ferrer *et al*., 2025), affecting visual, photogrammetric and surface remote-sensing techniques. This environmental dependence is evident in coastal drone monitoring (Graham, 2025) and underwater photogrammetry, where low visibility and currents can require substantial adaptation of acquisition procedures (Costa, 2022). Ocean warming and acidification may additionally modify marine communities and biofouling dynamics (Germinario *et al*., 2026b; Sesana *et al*., 2021), altering the visibility and legibility of archaeological surfaces.

Methods selected during planning from previously observed conditions may consequently require adjustment or combination with alternative techniques during fieldwork. For monitoring and preservation, changes in exposure, turbidity or biological coverage between successive surveys may also reduce the repeatability and comparability of observations. Maintaining feasibility therefore requires greater methodological flexibility, complementary techniques or repeated acquisition.

2.3 Operational Sustainability

The requirements associated with maintaining safety and feasibility converge on a third constraint: whether archaeological intervention can be sustained within available resources. Sufficient funding, time, personnel and technical capacity are fundamental requirements of archaeological project design and completion (ICOMOS, 1996; UNESCO, 2001; Maarleveld *et al*., 2013).
Safety and feasibility can increase these requirements through different but cumulative pathways. Reduced or less predictable operational windows require longer or repeated campaigns, mobilisation, personnel and vessel time; methodological adjustments may require additional equipment, specialised expertise or repeated acquisition. Where both coincide, the time available for intervention decreases while the resources required to achieve the same archaeological objectives increase.

Operational sustainability therefore depends on whether these additional demands can be absorbed without compromising the continuity or completion of archaeological intervention.

3. Towards Climate Change-Adaptive Coastal and Underwater Archaeology

The constraints identified above expose a fundamental limitation of predominantly reactive archaeological practice: its reliance on past experience to anticipate future working conditions. As climate change reduces the representativeness of this operational baseline, maintaining archaeological capacity requires complementing accumulated field experience with climate-informed predictive capacity.

Environmental monitoring can characterise ongoing change, while short-term forecasts and climate projections can provide information on how relevant environmental conditions may evolve across operational and longer timescales. Integrating these sources of climate information into archaeological decision-making can support anticipatory adaptation (Pérez-Alvaro, 2016; Breen, 2025; Wright & Hylton, 2024). Together, they can inform when and where interventions can be safely conducted, which methods are likely to remain feasible, and what resources may be required before these constraints materialise. Adaptive measures may include rescheduling fieldwork to suitable operational windows, adjusting working periods and safety protocols, selecting alternative survey or documentation techniques, and reallocating personnel, equipment or campaign time. At longer timescales, monitoring and projected change can also inform site prioritisation and the adjustment of monitoring and preservation strategies (**Fig. 2**).

The required transition is therefore not from reactive to predictive practice, but from reliance on reaction towards informed anticipation. Experience and reactive adjustment remain essential in inherently variable coastal and underwater environments, but can be complemented by observation and prediction to support proactive decision-making. Climate-adaptive archaeology would thus move from a predominantly experience-based and reactive operational model towards a climate-informed, predictive and proactive one, strengthening its capacity to maintain archaeological functions under changing environmental conditions.

4. Conclusions

Climate change poses a dual challenge to coastal and underwater archaeology, affecting both the archaeological record and the capacity

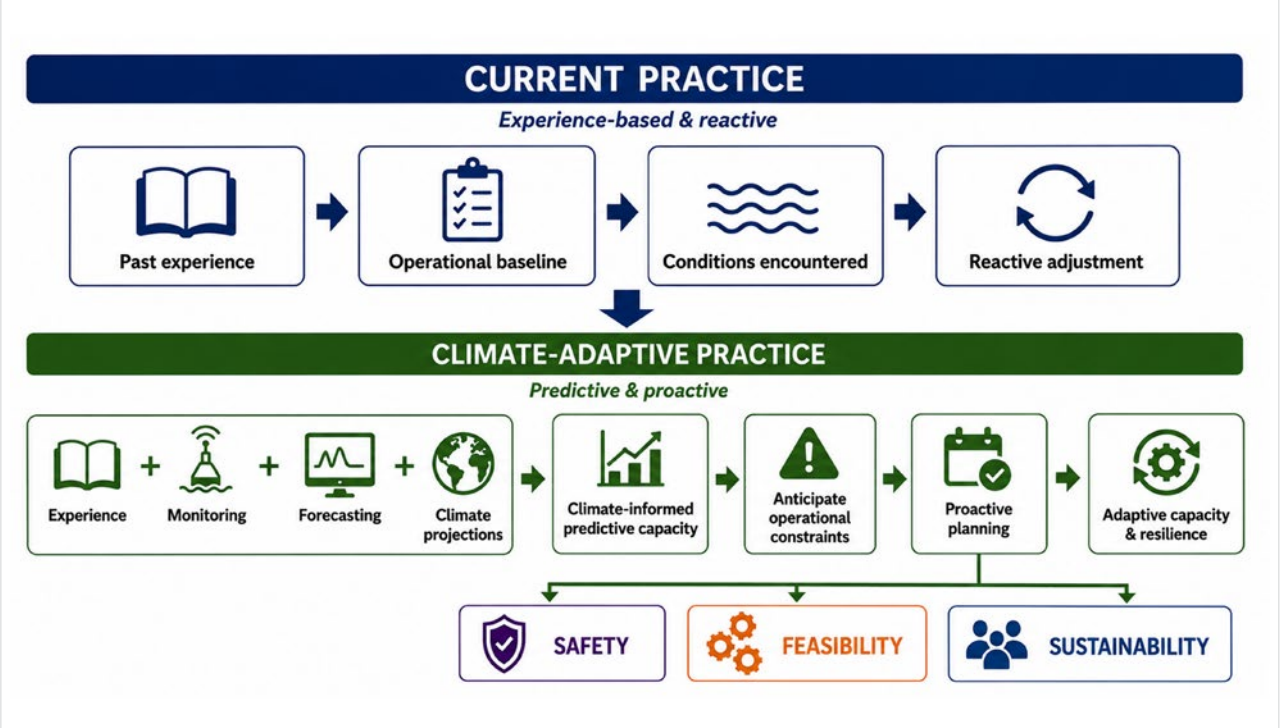


Figure 2- Towards climate-adaptive archaeological practice. Transition from an experience-based and predominantly reactive model towards a climate-informed, predictive and proactive approach integrating experience, monitoring, forecasting and climate projections to anticipate operational constraints and strengthen adaptive capacity and resilience.

to investigate, document and preserve it. As experience-based operational baselines become less reliable, increasing environmental uncertainty may constrain operational safety, feasibility and sustainability.

Addressing this challenge requires complementing accumulated experience and reactive adjustment with climate-informed predictive capacity. Integrating environmental monitoring, forecasting and climate projections can support a shift from predominantly reactive towards predictive and proactive archaeological practice, strengthening its adaptive capacity and resilience under changing environmental conditions.

IHCantabria is a joint research institute of the Universidad de Cantabria and the Government of Cantabria (Spain), specialising in environmental hydraulics. Its multidisciplinary research integrates field observations, laboratory experimentation and numerical modelling to address challenges including climate change, coastal risks, marine and coastal engineering, environmental management and adaptation. With more than 200 experts and extensive participation in national and international R&D projects, IHCantabria increasingly applies its expertise in climate science, risk assessment and coastal processes to cultural heritage, developing interdisciplinary approaches to understand climate-related threats and support the adaptation, management and preservation of coastal and archaeological heritage.



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CASE STUDIES



Photo Credit: GIRT Scientific Divers doing a condition survey of the Potentially Polluting Wreck El Capitan (1946) in Subic Bay, Philippines in 2025.

Climate Change and Cultural Heritage in the Eastern Mediterranean and Black Sea

Hakan Öniz and *Ceyda Öztosun*

Cultural assets belonging to past civilisations located in aquatic spaces often go undiscovered. Various threats (such as coastal erosion, frequent storms, increased salinity etc.) place these undiscovered unknown assets at significant risk of disappearing suddenly or gradually and consequentially, unrecorded. The locations discussed in this article features coastal communities living in close association with the sea, since the Paleolithic era. Traces of numerous cultures spanning the Neolithic, Bronze Ages, Iron Age, Roman and Byzantine eras, and into the Ottoman period exist not only on land, but underwater. Evidence of human habitation found in caves along Türkiye's Mediterranean coast (such as in Hatay and Antalya) and elsewhere in the Mediterranean region attests to the relationship between humanity and the sea during the Paleolithic era. Traces of human life also persist in caves now submerged (Pellet et.al., 2026), as well as in sunken settlements dating back to the Neolithic and Early Bronze Age (Ammerman, 2020, p.429).

To fully grasp the scope of underwater cultural heritage (UCH) in the Mediterranean, it is first necessary to understand the scale and regional geographical context. The Eastern Mediterranean region encompasses the Mediterranean coasts of Türkiye, Greece, Syria, Lebanon, Israel, Palestine and Egypt, as well as Cyprus and certain Aegean Sea islands (**Fig. 1)**. Connected to the oceanic system via the Strait of Gibraltar to the west and the Suez Canal to the southeast, these countries maintain links to various other aquatic systems: in the north, through the Black Sea (Türkiye, Bulgaria, Romain, Ukraine, Russia and Georgia coasts) and other waterways; in the east, via rivers such as the Asi (Orontes); and in the south, via the Nile. The coastline of the Sea of Marmara connects to the Aegean Sea via the Dardanelles measuring approximately 1,000 km. As an inland Turkish sea, it connects to the Black Sea via the Bosphorus. The coastline of the Black Sea, including the Sea of Azov (with which it merges in the north), spans approximately 4,869 kilometres. The Black Sea was a lake at the beginning of the Holocene epoch, connecting with the Mediterranean via the Sea of Marmara around 5500 BC, transforming it into a sea. It has distinct geographical characteristics and lower salinity levels than the Mediterranean. Freshwater flows into the Black Sea from Europe's second-longest river, the Danube, as well as the Dnieper (Dnipro), Don, Dniester (Dnister), Southern Bug (Boh) and Kızılırmak rivers. The coastal and underwater cultural heritage (UCH) of these countries is affected in various ways by climate change. Climate change poses a serious threat to landscapes, coastal and submerged archaeological sites, and climate-related disasters have increased over the past four decades, resulting in significant human and economic losses (Chatziandreou & Haupt, 2026; Dawson et.al., 2020; Perez-Alvaro, 2016, p. 842). This situation naturally applies to the coastal zones discussed in this article as well.

The Eastern Mediterranean and Black Sea coasts descibed above have a rich cultural heritage acting as international trade hubs for at least five millennia. This long history has witnessed thousands of maritime accidents, with numerous settlements established along the shore in the past are now submerged due to rising sea levels. Sea-level rise (SLR) is one of the main impacts of climate change threatening the coasts of the Mediterranean basin.



Figure 1- Sites mentioned in the text and Possible sea level rise by 2100-2150.

These coastal areas are becoming increasingly exposed to flooding, particularly in low-lying coastal plains, river deltas, lagoons and reclaimed land (Anzidei *et al*., 2023: 359). The Intergovernmental Panel on Climate Change (IPCC 2021) scenarios (in line with SSP 5-8.5) indicate that the global sea level is projected to rise by approximately one metre in extreme scenarios above current levels by 2100 (Fig. 1). Globally sea level has been rising over the last two centuries. In recent years, SLR is at rates of up to 3.2 mm per year, faster than in the last two millennia (Antonioli *et al*., 2020, p. 2). However, along the coasts of Türkiye, this rate appears to be slightly higher. Data on sea levels in Türkiye are obtained through national sea-level monitoring stations operated by the General Command of

Mapping (HGK), as well as via satellite altimetry. These programmes suggest that the rate of sea-level rise in the surrounding seas ranges from 4 mm to 6 mm per year (Yıldız *et al*., 2003; Simav *et al*., 2015, p. 2). Alongside these effects, storm surges, waterspouts and marine-induced flooding are increasing the risk to coastal and UCH assets.

Measurements from the Turkish State Meteorological Service's marine meteorological observation systems between 1970 and 2021 indicate an increase in sea surface temperatures of approximately 0.4 – 1.4°C across the Black Sea, Sea of Marmara, Aegean Sea and Mediterranean Sea over the last twenty years. During this period, maximum increases ranged from 2.3°C to 3.5°C, primarily observed in the Black Sea (Demircan, 2022: 96). According to reports by the Turkish Meteorological Service, there has been a noticeable increase in the number of disasters occurring in Türkiye between 1940 and 2022 (**Tab. 1**). The 7,319 km² of Turkish coastal areas situated below 10 metres; coastal topography revealed that the coast of Marmara region poses the greatest risk, while the Mediterranean coasts face the greatest risk of land loss (Yıldırım & Gencer, 2021, p. 246). Topographical changes are particularly significant in their direct impact on coastal and UCH. Undoubtedly, a similar impact applies to the entire coastlines discussed in this article.

It should be noted that studies concerning changes in temperature, salinity and chemical composition across these seas, and the impact of such changes on archaeological artefacts have not yet reached sufficient levels or volumes (Gregory et.al 2022). In this context, conducting multidisciplinary research in collaboration with archaeological conservation scientists and archaeologists is crucial. Due to increasing temperatures, it is anticipated that the Mediterranean will become increasingly salinic over the coming century. Ultimately, it is clear that current measurement capabilities with regard to the various factors influencing Mediterranean salinity and climate variability are inadequate (Öniz and Gültekin, 2024; Marcos *et al*., 2008). One example of a group of marine species that has spread in response to climate variability, is Teredo sp. UCH sites, such as shipwrecks, contain various organic materials susceptible to biological degradation. Depending on environmental conditions, a wide range of organisms can cause various types of biological deterioration in organic archaeological material (González-Duarte *et al*., 2018; Öniz and Gültekin, 2024). Given its distribution in the Mediterranean and its destructive impact on wooden UCH, Teredo sp. poses a significant biological threat. As an example relating to a shipwreck, provided environmental conditions are favourable combined with a protective sediment layer that does not form rapidly, Teredo sp. can quickly destroy the wooden

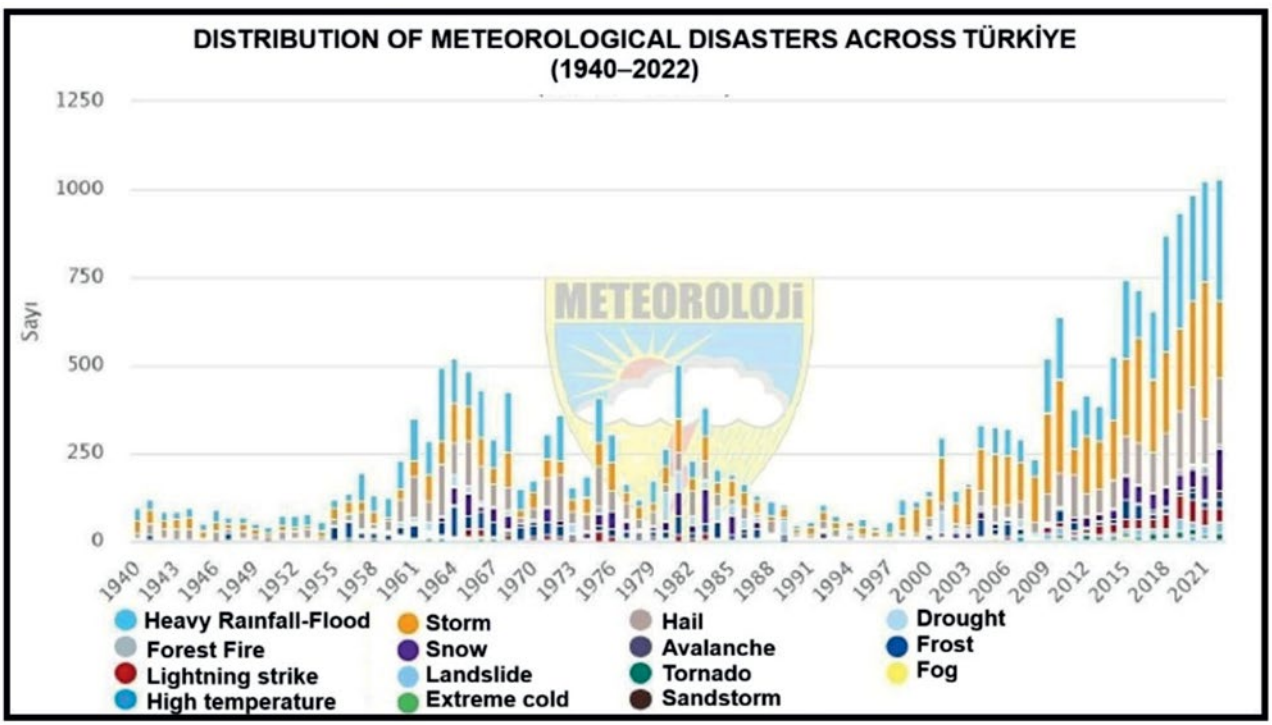


Table 1- Regional Disasters-Report from Turkish Meteorology Instituon – 2023.

components of a wreck, leaving behind calcium-rich tubular structures (Gregory, 2009, p. 4). This species is known to live and reproduce more rapidly in relatively temperate and saline waters (Hoagland, 1986, p. 88; Manders, 2011, pp. 13–14; Öniz and Gültekin, 2024).

Selected regional archaeological remains impacted by climate change:

Coastal erosion: Angurina-Beylikdüzü, Istanbul

As in many other coastal areas of the Mediterranean and Black Sea regions, coastal and underwater archaeological remains are present in Istanbul waters and also affected by corrosive processes. During studies conducted in 2011 along the coast of the Beylikdüzü district, the remains of a shipyard or granarium belonging to the ancient site of Angurina, dating from the 4th to the 9th century CE (spanning the Early Roman and Byzantine periods), were uncovered (Öniz et.al., 2017, Öniz et.al., 2014). As the structure is in direct contact with the sea and facing the risk of destruction due to wave action (**Fig. 2**) a proposal was made to construct an offshore breakwater to protect the structure.

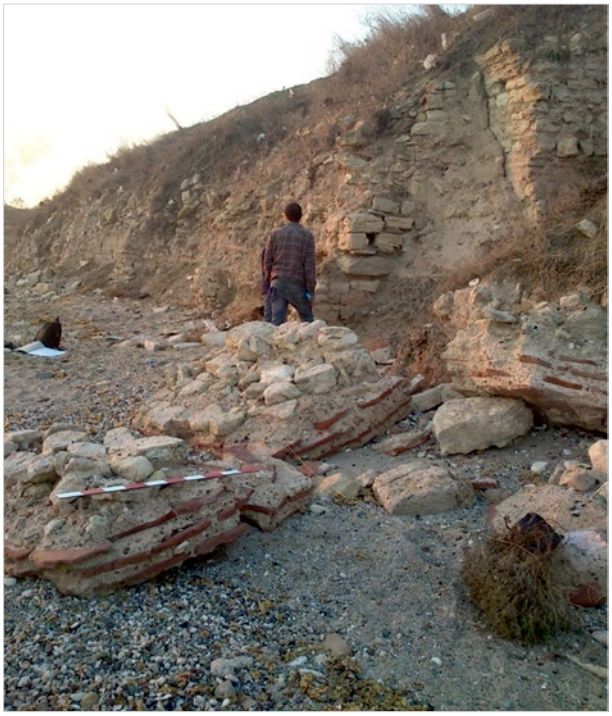


Figure 2- Shipyard or granarium structure on the shore – Anguria – Beylikdüzü (Photo: Hakan Öniz).

Frequent storms, tornadoes and increased precipitation: The ancient cities of Phaselis and Olympos in Antalya

Natural phenomena such as storms, floods and tornadoes can be linked to climate change in many parts of the world (Lyddon *et al*., 2020, p. 20). Research into wave climate and storm characteristics over the last 40 years has revealed an increase of over 20% in CFSR data for the North Aegean Sea, and an increase of over 15% for the southern (Egyptian) and eastern (Lebanese and Phalestine/Israeli) coasts of the Levantine Basin (Gumuscu et.al. 2025). Similar trends have also been observed along the coast of Antalya. The city of Phaselis and its surrounding forests have been impacted by these natural forces, while increased rainfall has affected Olympos, a city established along a watercourse. During a tornado in 2019, the resulting vortex uprooted around 1,500 trees and damaged the city's ancient ruins (Hürriyet Newspaper). Meanwhile, heavy rains swept some of the archaeological remains along the Olympos coastline into the sea. The authors of this article have since documented these remains on the seabed. Hundreds of ancient settlements, such as Phaselis and Olympos, are located along Türkiye's 8,500-kilometre coastline. Archaeological sites originally built above the highwatermark or currently situated in coastal zones face a direct threat of erosion caused by natural forces, as seen in the case of Angurina. This erosion process is triggered by the direct impact of waves and the indirect effects of seawater. In recent years, the Turkish Ministry of Culture and Tourism has funded the 'Legacy for the Future Project', which has supported 255 archaeological excavation projects, including those in the cities of Phaselis and Olympos. The project focuses on restoring and structurally reinforcing buildings in these areas, with a significant portion of the budg*et al*located to coastal cities.

Potential submerged Paleolithic settlements

Since humans inhabited caves during the early Holocene some caves are now underwater. An example is the Üçağızlı Cave system in Hatay dating to between 44,000-29,000 BP (Güleç and Baykara, 2014, p. 151) Excavations have been underway for many years. Despite being located at

depths ranging from 1-30 metres below the current sea level, it is believed they contain traces of human activity. (**Fig. 3**). Findings indicate that the Ukrainian continental shelf, which became dry-land when sea levels dropped to their lowest point during the last Ice Age, was a steppe region likely heavily utilised by hunter-gatherers migrating from west to east and from northwest to south. Research conducted off the coast of Ukraine has identified three potential Late Paleolithic archaeological sites at depths of 20–22 metres (Kadurin *et al*., 2020, p. 414).



Figure 3- Taking samples from the entrance rock to search obsidian, flint Stones or animal bones in a sunken cave. Hatay Keldağ Üçağızlı Cave System (Photo Hakan Öniz).

Submerged Neolithic and Early Bronze Age Sites:

Submerged Neolithic and Early Bronze Age settlements:

These submerged settlements are found in various regions, particularly along the Black Sea coast, as well as to a lesser extent along the coasts of the Sea of Marmara and the Mediterranean. One such settlement is located off Avşa Island in the Sea of Marmara and dates to the Mesolithic (c. 12,000–10,000 cal BP), Neolithic (c. 10,000–5,000 cal BP) and Bronze Age (Öniz, 2019) periods (see **Fig. 4**). The remaining two Neolithic settlements are the partially submerged Isıldaktepe Altı site in the Dardanelles and the Selimpaşa Mound on the Sea of Marmara coast (Aslan & Polat, 2013; Aydingun *et al*., 2014). Another prehistoric settlement is located at Limantepe in the Urla district of Izmir (Şahoğlu *et al*., 2022). There are numerous underwater settlements dating to both prehistoric and historical periods along Türkiye's coasts (**Fig. 5**). While tectonic movements are considered to be the primary cause of their submergence, rising sea level during the Holocene is recognised as a secondary factor. As all of these settlements are located at shallow depths, they have become increasingly vulnerable to the impacts of climate change.



Figure 4- Avsa Island submerged jar grave (Photo Günay Dönmez).

Results

The impact of climate change on the regions mentioned above is undoubtedly far greater than can be described in this brief text. Shipwrecks in shallow waters and their cargoes are particularly vulnerable to increasingly frequent and more

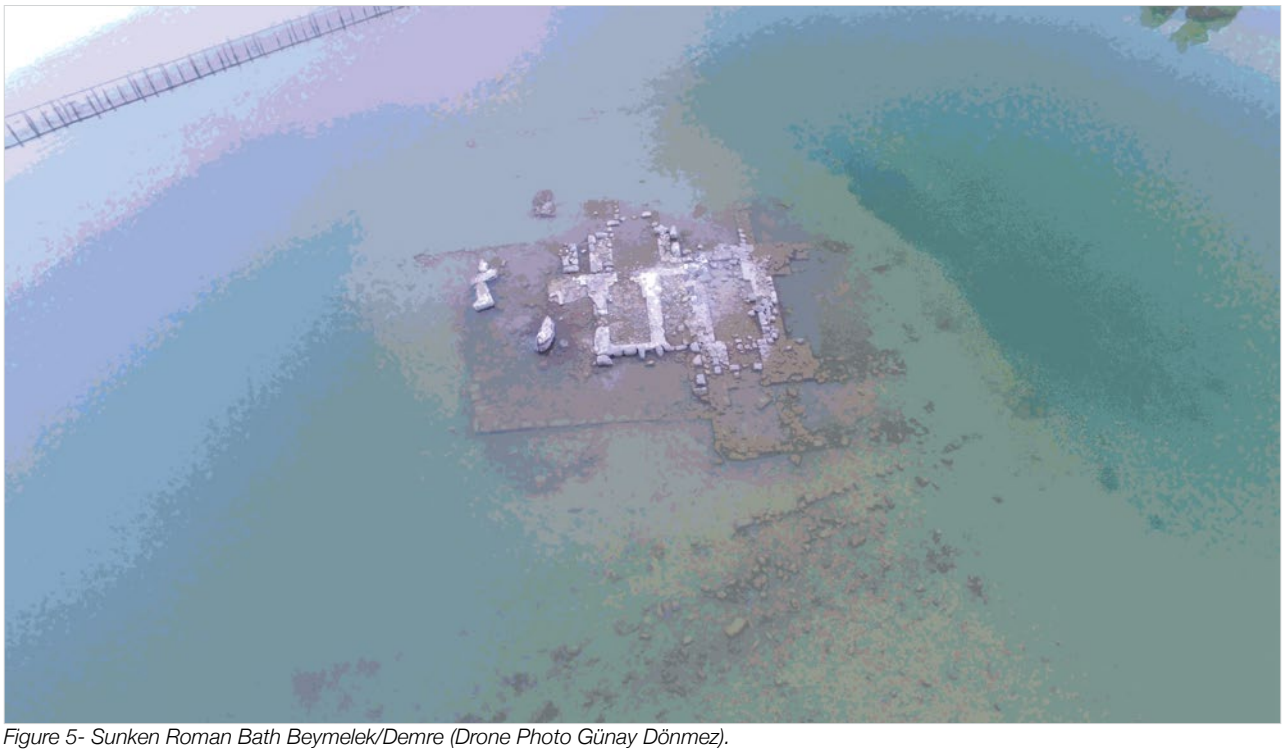


Figure 5- Sunken Roman Bath Beymelek/Demre (Drone Photo Günay Dönmez).

powerful storms. In this context, studying, documenting and preserving shipwrecks, of which less than one-thousandth have been investigated globally, is of great importance. It is also important to remember that shipwrecks, ancient coastal structures and the remains of prehistoric submerged settlements — the vast majority of which have yet to be discovered or documented — represent invaluable and irreplaceable cultural heritage assets from ancient civilisations. Ultimately, it is crucial to protect and record these sites in parallel with investigating the impact of climate change on cultural heritage.

The CMAS (Confédération Mondiale des Activités Subaquatiques), also known as the World Underwater Federation, is an international non-profit organisation established in Monaco in January 1959. It oversees underwater sports, scientific research and recreational scuba diving training on a global scale. It has more than 120 member national federations across six continents. Headquartered in Rome, Italy, the federation counts the world-renowned Jacques-Yves Cousteau among its founders and is recognised by the International Olympic Committee (IOC). It comprises three main committees. The first is the Technical Committee, which manages recreational scuba diving standards and international certification levels. The second is the Sports Committee, which organises competitive underwater sports such as fin swimming, underwater hockey and underwater rugby. The final body is the Scientific Committee, which focuses on marine biology, nature and environmental conservation, scientific diving and underwater cultural heritage. Within the CMAS Scientific Board, the Scientific Diving Directorate is led by Prof. Emad Khalil, an ICOMOS-ICUCH member, and the Underwater Cultural Heritage Directorate is led by Prof. Hakan Öniz, also an ICOMOS-ICUCH member.
Dr Ceyda Öztosun, who is also an ICOMOS-ICUCH member, serves on the same board.

Akdeniz University is a leading institution in its region, with a robust research infrastructure and active, competent academic staff. It serves as a national model and is a preferred choice for its internationally recognised research. The university is committed to contributing to society through a pioneering and collaborative educational approach, and aims to cultivate innovative, creative and inquisitive individuals. Akdeniz University envisages itself as a research-oriented institution that shapes the future through world-class research, leads in science and technology, and fosters individuals who are creative, ethically conscious and dedicated to lifelong learning. Akdeniz University comprises 24 faculties, around 2,800 academic staff members, and approximately 80,000 students.
It offers a Master's degree programme in Underwater Archaeology through the Department of Mediterranean Underwater Cultural Heritage, which is part of the Mediterranean Civilisations Research Institute. The university conducts underwater excavations and research along Turkey's Mediterranean coast via the Underwater Archaeology Research and Application Centre in Kemer, and also supports projects in other countries. As a full member of the UNESCO UNITWIN Underwater Archaeology Network, the university runs international underwater archaeology training programmes in partnership with UNESCO and CMAS.



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Dr. Oniz completed his undergraduate studies in the Department of Art History and Archaeology at Eastern Mediterranean University. He went on to complete his master's and doctoral studies in the field of underwater archaeology at Selçuk University in Konya, Turkiye. He is Chair of the Department of Mediterranean Underwater Cultural Heritage at the Institute for the Study of Mediterranean Civilisations at Akdeniz University, Chair of the Department of Cultural Heritage Restoration and Conservation in the Faculty of Fine Arts, and Director of the Kemer Underwater Archaeology Research Centre at the same university. He serves as Chair of the Underwater Cultural Heritage Monitoring Group of the UNESCO National Commission of Turkiye and as Director of Underwater Cultural Heritage on the Scientific Committee of CMAS (the World Underwater Confederation). He is also a member of ICOMOS-ICUCH (the International Committee on Underwater Cultural Heritage) and an expert member of the ICOMOS Turkiye National Committee. He is also one of the founders and the first coordinator of the UNESCO UniTwin Underwater Archaeology Network (2012–2015). . Dr. Oniz conducts underwater archaeology research and excavation projects along Turkiye's Mediterranean coast, and teaches courses on underwater archaeology and photography at undergraduate, postgraduate and doctoral level at various universities in Turkiye and Europe.

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Climate-related threats to archaeological sites along the Bulgarian Black Sea coast

Nayden Prahov

The Black Sea is changing. Rising water temperatures and changing patterns of extreme weather and increases in the mean wave power (Valcheva *et al*. 2026; Pham *et al*. 2025; Islek *et al*. 2022; Islek *et al*. 2025) are part of a wider climate trend. Along the Bulgarian coast, these processes interact with human activities such as harbour construction, dredging and the building of coastal defences (Prahov *et al*. 2021), creating combined pressures on the region's natural and cultural maritime heritage. Long-term data monitoring in substantial areas of the Bulgarian coast remains limited, making it difficult for scientists to determine the precise contribution of climate change to the impacts. The impacts themselves also remain poorly studied and are documented only fragmentarily. The Intergovernmental Panel on Climate Change (IPCC) identifies waves, storms, coastal erosion and changes in sediment movement as important coastal hazards.

Shipwrecks, prehistoric settlements, ancient harbours and submerged fortifications may have survived for centuries or even millennia because they were protected by layers of consolidated strata and seabed sediments. Once this protective cover is disturbed or removed by stronger wave action and nearshore currents, the exposed remains can be rapidly damaged by waves, currents, marine organisms and human interference. Several recent cases from the Bulgarian Black Sea coast provide warning signs of how climate-related hazards, sometimes acting together with local engineering works, can increase the risk to underwater cultural heritage.

Aheloy beach: damage to prehistoric settlements and a shipwreck

In autumn 2025, the Centre for Underwater Archaeology, subsequently renamed Underwater Heritage Institute (UHI), received reports of archaeological material washed onto the beach between the towns of Pomorie and Aheloy. UHI team members documented hundreds of pottery fragments from submerged Chalcolithic (fifth millennium BC) and Bronze Age (third millennium BC) settlements scattered along approximately three kilometres of coastline. Pointed wooden posts from prehistoric buildings (**Fig. 1**) and timbers from a shipwreck were also found. Diver inspection and geophysical surveys identified one of the source sites: a nineteenth-century sailing ship, probably built in the Mediterranean. The prehistoric sites could not be located.

The artefacts were washed ashore by storms accompanied by strong wave action. Although the storms were intense, they were not considered exceptional for the season. Nevertheless, remains that had survived on the seabed for hundreds and thousands of years were disturbed. UHI divers found large areas where the sand had disappeared, and the underlying clay was exposed. The most likely explanation for the loss of sand is a combination of wave energy and altered sediment transportation. Changes in the predominant wind and the prevailing coastal currents can temporally remove sand from one area and deposit it elsewhere, significantly changing the coastal morphology. Climate change may influence these processes, but more observations are needed before its precise contribution can be established.



Figure 1- Wooden piles from buildings belonging to prehistoric settlements, washed ashore on the beach between Aheloy and Pomorie.

Atliman Bay: climate and construction pressures

A similar case was recorded in 2023 in Atliman Bay north of Kiten. Following information shared by local inhabitants, archaeologists found visible remains of three wooden vessels on the seabed at depth about 1-1.5 m. Residents recalled at least one more wreck. In many places in the small bay, both underwater and on the beach, the sand had been removed and the clay substrate beneath it was exposed. The survey also recorded prehistoric pottery, wooden posts of a jetty, and the remains of an ancient forest.

Local people connect the gradual loss of sand with a breakwater built south of the bay some 20 years ago. As a result, it may have changed the coastal currents and sedimentation processes related to them. Climate change impacts should be considered along with the coastal development: engineering works can intensify erosion or alter sediment distribution, while coastal currents and changing wave conditions add further pressure. Such compound risks must be assessed before new infrastructure is approved elsewhere along the coast.

Gradina Bay: ship timbers on the beach

During the winters of 2023 and 2024, ship timbers – mainly frames and planking – were washed ashore along several kilometres of coastline at Gradina Bay near Sozopol (**Figs. 2a** and **2b**). No underwater inspection was carried out. Local observers reported that prolonged periods of wind sometimes change coastal currents and move large amounts of sand, temporarily exposing the shipwrecks on the seabed.

Kiten South Bay: shipwrecks and a prehistoric settlement

Comparable processes are regularly reported from Kiten South Bay, where at least five wooden shipwrecks and a submerged Early Bronze Age settlement are known. Members of the local Marina Diving Club regularly inform the UHI when shipwrecks or prehistoric building posts become exposed or are buried again. These reports are extremely valuable because they provide evidence that testify to the dynamics of the sediment changes in the bay.



Figure 2a- Fragment of a ship's frame, possibly a floor timber or futtock, washed ashore at Gradina Bay.



Figure 2b- Fragment of a ship's frame, possibly a floor timber or futtock, washed ashore at Gradina Bay.

Divers elsewhere along the Bulgarian coast describe similar patterns. Prolonged winds (usually from the south or west) may temporarily alter currents usually shaped by the prevailing northern and north-eastern winds. Sand is removed, archaeological sites become exposed, and the prevailing currents later cover them again. In such moments sites and artefacts may be scattered, damaged, washed ashore or looted.

The submerged walls of ancient Nessebar

Nessebar, a UNESCO World Heritage property, contains important heritage both on land and underwater. Its submerged fortifications and harbour structures were first studied by the Bulgarian underwater archaeologist Lyuba Ognenova between 1960 and 1984.

On the south-eastern side of the Nessebar peninsula, at a depth of about 2 metres, Ognenova documented a fortification wall known as the L-shaped Wall. Its main section extended for about 45 metres, then turned and continued for approximately another 17 metres (Preshlenov 2012, 509-510).

When regular underwater research at Nessebar were resumed by UHI in 2017, the shorter section and the turn were no longer visible (**Fig. 3**). Repeated visits in later years confirmed this observation. One possible explanation is that strong wave action broke up this part of the structure and displaced its blocks. The exact date and cause cannot be



Figure 3- Plan of the L-shaped Wall documented by Lyuba Ognenova in 1980's, overlaid with a photomosaic showing the wall's condition in 2025.

proven. A severe storm in the winter of 2012–2013 demonstrated the power of local waves when it removed the dense seaweed cover, revealing a previously unknown wall close to the southern shore of the peninsula.

From emergency response to climate adaptation

Together, these cases show an increased negative impact on underwater cultural heritage. The climate changes undoubtedly add their pressure through changing coastal hazards. Local effects will differ, and protection must therefore be based on evidence, observation and site-specific planning.
Practical steps are urgently needed. Bulgaria should establish long-term monitoring at high-risk sites and zones, combining diver inspections, photogrammetry and sonar documentation, with records of sediment movement and accumulation, waves, currents and storms. A rapid-response system should allow authorities, divers, fishers, residents and municipalities to report exposed remains for prompt archaeological inspection. Baseline records and repeated three-dimensional models would help identify change, assess vulnerability and set priorities. Where damage is likely, responses may include *in situ* stabilisation, protective covering, detailed documentation, excavations and recovery of objects, and stronger surveillance against looting.

The Bulgarian Black Sea coast holds an exceptional record of human past, cultural and spatial exchange, and adaptation over thousands of years. Much of it remains preserved beneath the seabed, but that protection can no longer be taken for granted. Bulgaria should establish a long-term programme to strengthen the resilience of its underwater cultural heritage by linking archaeological monitoring with climate and ocean data, involving local communities and planning coastal development more carefully.

The National Archaeological Institute with Museum *at the Bulgarian Academy of Sciences is Bulgaria's leading institution for archaeological research. It studies, preserves and presents the country's archaeological heritage. The Institute conducts excavations and interdisciplinary research throughout Bulgaria, while its museum in Sofia holds and displays some of the country's most important archaeological collections.*

UNDERWATER HERITAGE INSTITUTE

The Underwater Heritage Institute *under the Ministry of Culture of Bulgaria is the national institution for underwater archaeology and a UNESCO Category 2 Centre. Based in Sozopol, it carries out archaeological research, documentation, conservation, training and public outreach. The Institute promotes international cooperation and supports the protection and sustainable management of underwater cultural heritage in Bulgaria, the Black Sea and the Lower Danube regions.*



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Climate-Related Risks to Underwater and Riverine Archaeological Heritage along the Lower Danube

Aleta Guadelli, and *Nayden Prahov*

The conservation of the archaeological heritage along the Bulgarian segment of the Danube River requires constant monitoring of the archaeological sites, with a focus on the natural and climate-related processes affecting their integrity, authenticity and overall condition. Particular attention is being paid to the eighteen component parts of the site on the UNESCO Tentative List, Frontiers of the Roman Empire – the Danube Limes in Bulgaria. Although most archaeological sites are currently in relatively good condition after the assessment of the Nomination Dossier for the inscription of the property on the UNESCO World Heritage List. A A significant proportion of the remains are preserved underground or submerged in the riverbed: they are exposed to various natural and man-made threats. Increasingly significant risk factors include floods, droughts and extremely low water levels, riverbank erosion, changes in sediment transport, and fluctuations in temperature and humidity. Their impact depends on the interaction between hazard, exposure and vulnerability (IPCC 2022; EEA 2024).

UNESCO notes that archaeological sites along the Bulgarian section of the Danube have already been affected by flooding and erosion, whilst changes to the river channel and regulation works carried out during the 20th century have further impacted the condition of riverside monuments. These processes may lead to the exposure of underwater remains, the disturbance of archaeological strata and, in the event of repeated cycles of drying out and wetting, to accelerated deterioration and looting.

Although most archaeological remains are relatively stable, a number of sites are increasingly exposed to geological and hydrological hazards. Consequently, risk assessment at the individual site level is essential for effective and adaptive management.

In August 2026, exceptionally low water levels in the Danube revealed parts of the foundations of Constantine's Bridge (**Fig. 1**), harbours structures associated with Bononia and Dimum, the Roman limestone quarry at Gorni Vadin, remains of the fortifications of Appiaria (**Fig. 2**) and other archaeological remains, which are otherwise submerged when water levels are elevated. The Underwater Heritage Institute (UHI) and National Archaeological Institute with Museum – Bulgarian Academy of Sciences (NAIM-BAS) carried out further monitoring following the survey conducted in the spring of 2026 by representatives of the National Institute of Immovable Cultural Heritage (NIICH) and the UHI. The condition of specific features was assessed, including the cut stone blocks and the quarry negatives from the extraction of cut stone blocks, preserved in situ at Gorni Vadin; the bridge steps at Ulpia Oescus; and the stone accumulations associated with presumed harbour structures at Dimum.

The initial detailed assessment focuses on three priority riverside and underwater sites:

Gorni Vadin – an Early and Late Roman limestone quarry: An ancient limestone quarry exposed to riverbank erosion, slope instability and associated geological processes. Despite the exceptionally low water level at this stage, no significant changes in the condition of the site have been observed, nor has any increased erosion been noted.

Constantine's Bridge which is related with Gigen / Oescus – Early Roman legionary fortress; Roman

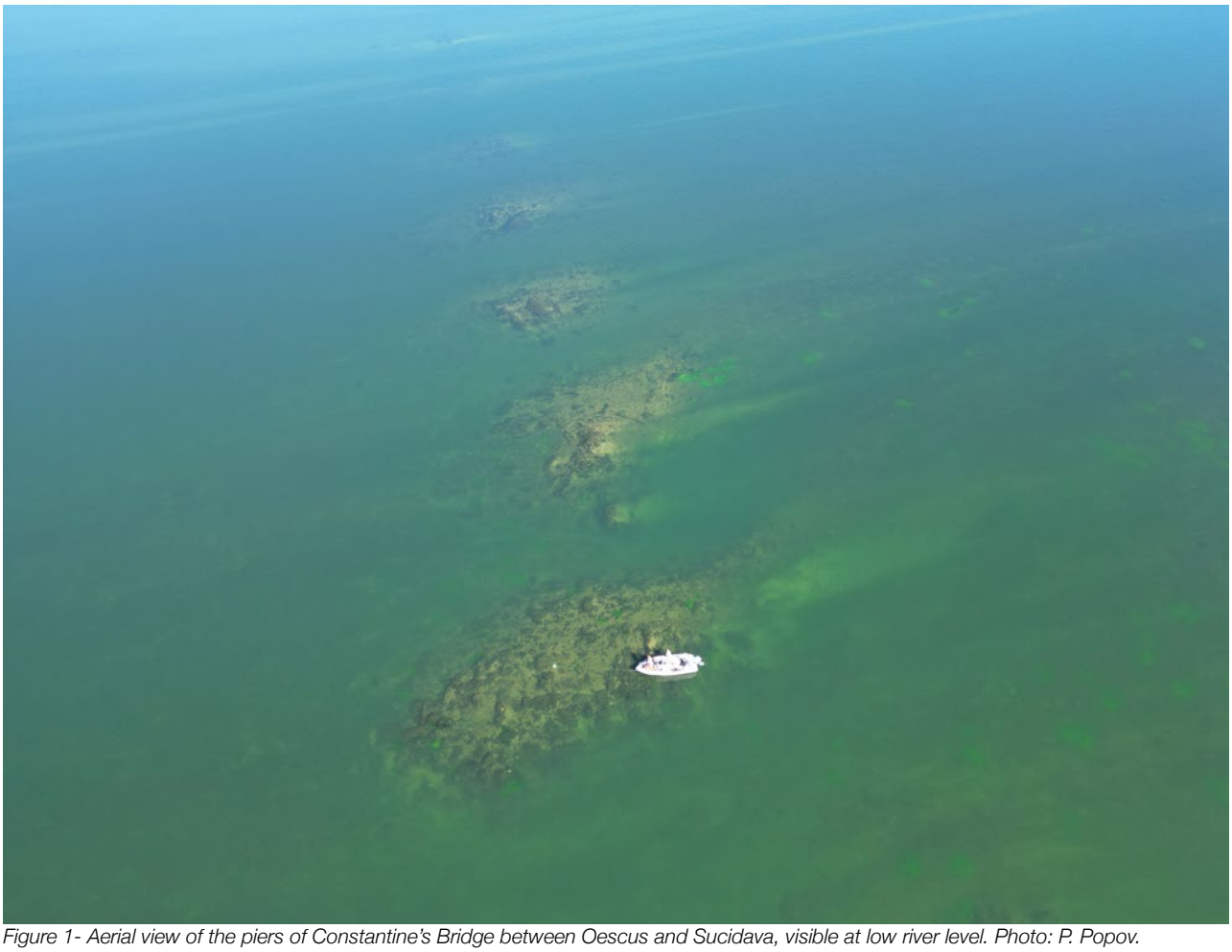


Figure 1- Aerial view of the piers of Constantine's Bridge between Oescus and Sucidava, visible at low river level. Photo: P. Popov.



Figure 2- Remains exposed by the low Danube water levels, presumably part of the fortification system of Appiaria. Photo: N. Prahov.

city (colonia); Late Roman legionary fortress; Late Roman and Early Byzantine fortified city: A significant monumental complex associated with Constantine's Bridge, comprising submerged and shoreline remains and the approaches to the bridge (**Fig. 3**). These are particularly vulnerable to changes in the riverbed, erosion caused by the current, and fluctuations in the discharge and water levels of the Danube. The low river level has revealed new artefacts, archaeological structures (possibly harbour-related) and architectural elements, and has made it possible to assess the condition of the bridge's piers, including part of their steps. No signs of damage or deterioration were noted.

Possible harbour structures of Belene / Dimum – Early and a Late Roman auxiliary fort; a Late Roman and Early Byzantine fortified settlement: A fort and customs station with presumed harbour structures and riverbank walls, exposed to the effects of flood cycles, fluctuations in water level, riverbank erosion and changes in the river's dynamics. The structures, previously identified through bathymetric surveying and underwater inspection as potentially associated with the harbour, were documented in detail, and an assessment of their condition is still ongoing.

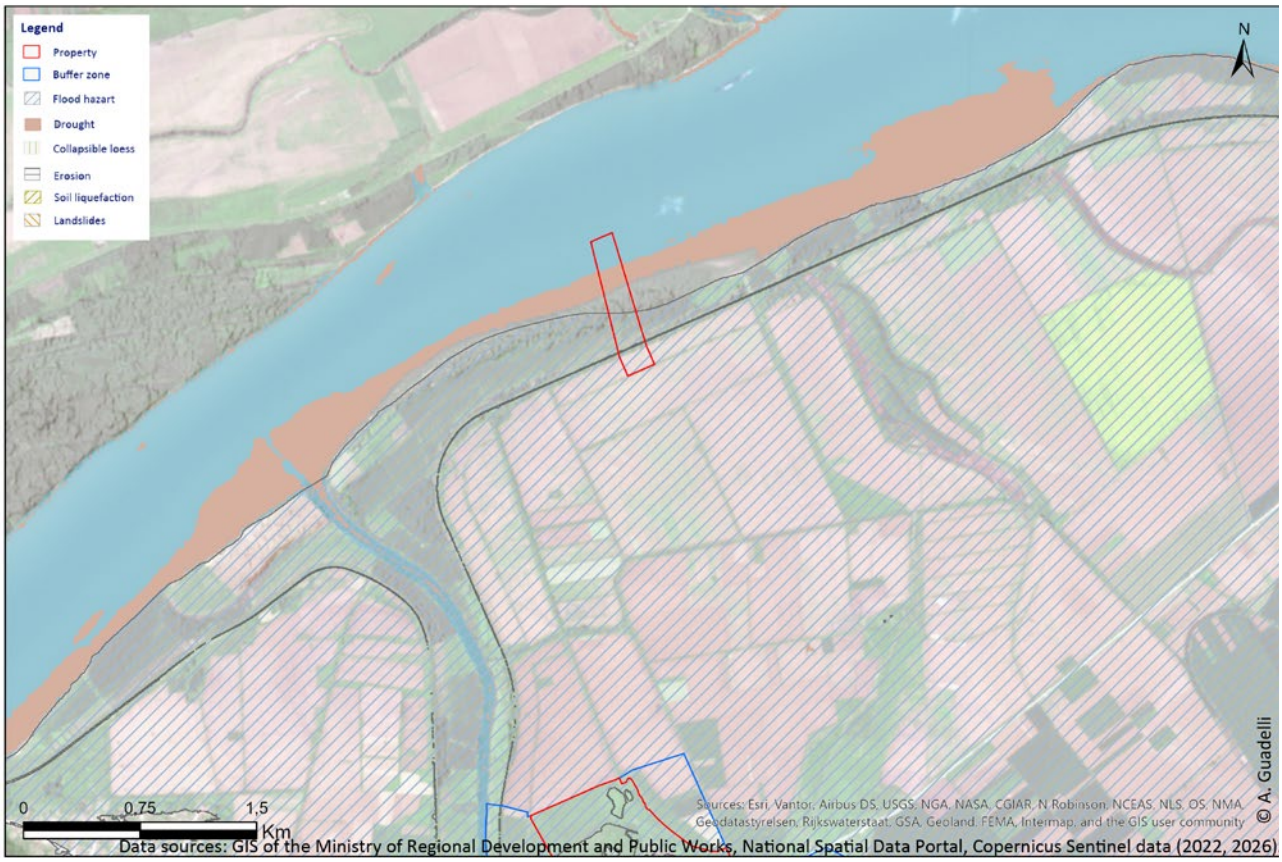


Figure 3- Climate and geohazard assessment of the Oescus archaeological site and its surrounding area. The map shows the property boundary and buffer zone, with the spatial distribution of flood hazard, drought, collapsible loess, erosion, soil liquefaction and landslide susceptibility. Data sources: GIS of the Ministry of Regional Development and Public Works, National Spatial Data Portal, and Copernicus Sentinel data (2022, 2026). Map: A. Guadelli.

While preparing the Conservation and Management Plan for the Bulgarian components of the nomination, a risk matrix was developed to systematically and comparatively assess identified threats. The matrix considered the probability of a particular risk occurring alongside its potential impact on the authenticity, integrity and current condition of the heritage properties. The following weighted risk matrix was selected as the most appropriate method for this specific case: WR = 0.35 Geological risk + 0.25 Seismic risk + 0.25 Flood risk + 0.15 Drought risk (**Fig. 4**). The fifteen percent weighting assigned to drought reflects its current contribution within the framework of the multi-risk assessment and should not be considered as a quantitative assessment of the contribution of climate change to the overall risk to the sites.

The drought risk assessment is based on data for the month of August from the nearest hydrometric station, taking into account the observed long-term downward trend in water levels in the River Danube (**Fig. 5**). These observations are also confirmed by climate simulations for the Danube river basin (Stagl, Hattermann, 2015; Probst, Wolfram Mauser, 2023), based on IPCC climate scenarios (SRES A1B, as well as RCP2.6, RCP6.0 and RCP8.5). Model projections indicate a significant and sustained reduction in river flow during the summer (June–August) and autumn (September-November) for the Middle and Lower Danube, due to a combination of higher temperatures and lower summer rainfall, which increases the risk of extreme summer low water levels in August, confirming the downward trend observed in historical records since 1941.

A conservative approach was adopted to assess the risk of flooding, using the highest value from the 30-, 100- and 1,000-year flood scenarios. Due to rising temperatures, the snowfall line is shifting to higher altitudes, and the spring snowmelt is occurring earlier in the year. This leads to a shift in peak water flows from spring to winter and early spring. Consequently, the risk of winter and early spring flooding is increasing, which supports the application of a strict precautionary approach in the calculations for 30-, 100- and 1,000-year flood waves.

The natural and climatic risk assessment, which has already been developed, is currently being revised by incorporating data from field observations, bathymetric data and underwater surveys carried out in August and September 2026, which reflect the exceptionally low levels of the Danube and allow for the inclusion of the archaeological remains uncovered under these conditions. The assessment remains preliminary and will be supplemented in stages.

The overall risk assessment highlights significant differences in the nature, intensity and spatial distribution of the risks affecting the Danube Limes. Geological processes represent a significant long-term threat, while flooding, erosion, seismic activity and extremely low water levels increase the vulnerability of a number of constituent parts. In the context of climate change, changes in the frequency and intensity of climate hazards, including heavy precipitation, river flooding, drought and associated periods of low river flow, may further increase the exposure and vulnerability of archaeological heritage. In accordance with the IPCC risk framework, climate risk results from the interaction of climate hazards with the exposure and vulnerability of heritage assets. The interaction between these risks – and in particular the successive occurrence of droughts and floods, which are directly linked to climate change –

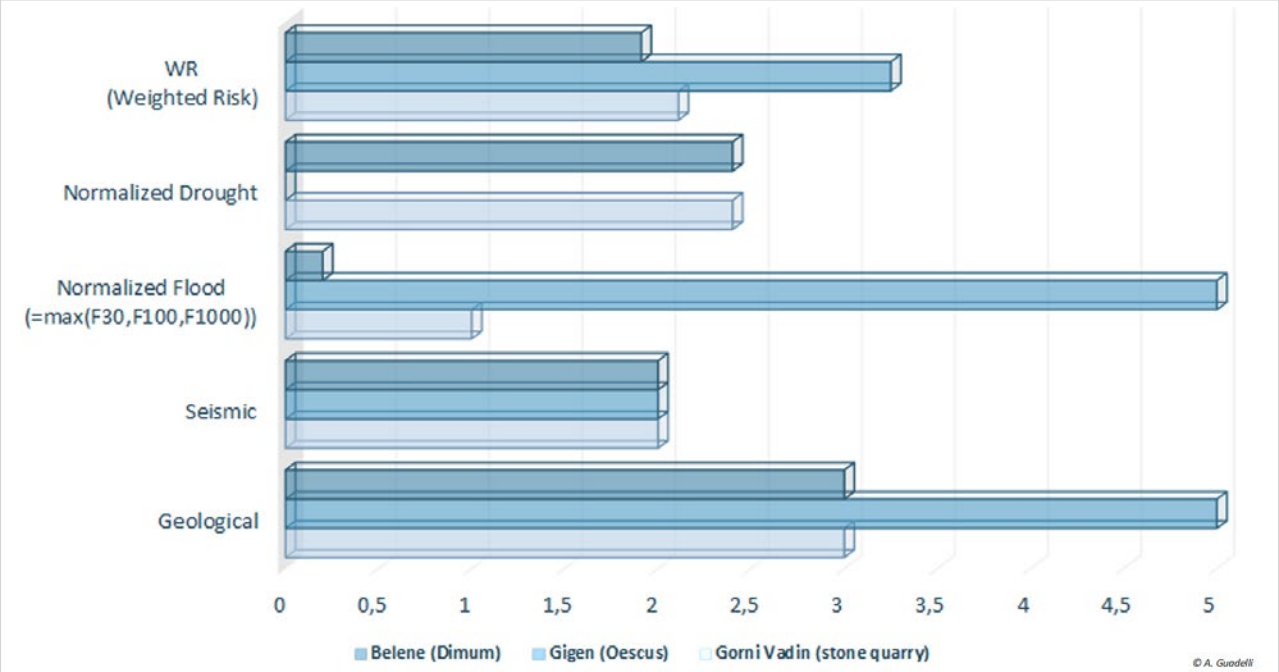


Figure 4- Comparative risk assessment of the Dimum, Oescus and Gorni Vadin archaeological sites. The chart presents normalized values for geological, seismic, flood and drought hazards, with Weighted Risk. Flood risk is represented by the maximum normalized value among the 30-, 100- and 1000-year flood scenarios. Graph: A. Guadelli.

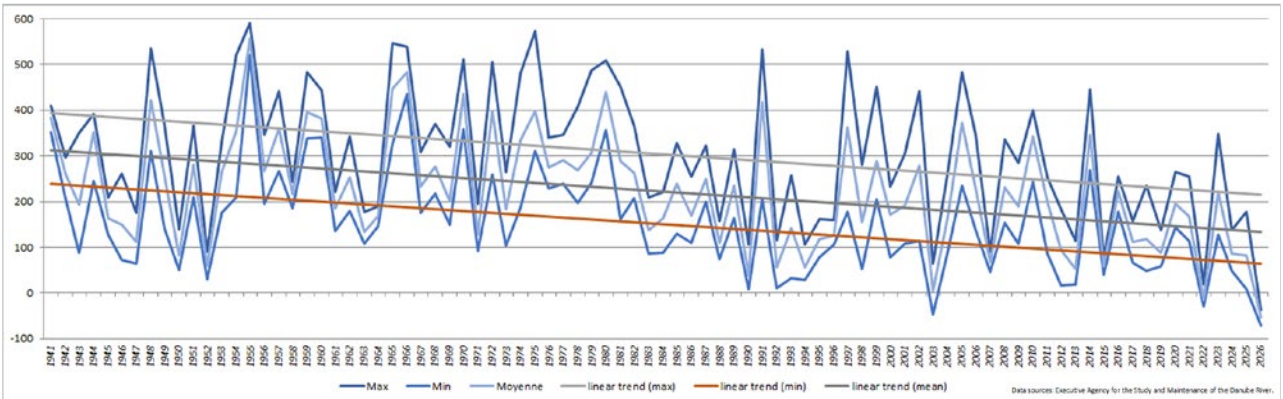


Figure. 5- Annual maximum, mean and minimum water levels of the Danube River at Svishtov, 1941–2026, with linear trends showing a decline of about 180 cm over the period. Source: Executive Agency for the Study and Maintenance of the Danube River (EASMDR). Graph: A. Guadelli.

highlights the need for site-specific monitoring and adaptive management. Once the analyses have been completed, appropriate measures for conservation and risk mitigation will be proposed, along with a monitoring system tailored to the observed trend of a steadily falling water level in the Danube River. The system will ensure regular monitoring of changes in water levels, exposure conditions and the condition of the archaeological remains, whilst allowing management measures to be adapted as new data becomes available.

The integrated risk analysis provides a basis for identifying sites requiring priority monitoring and conservation measures, and supports risk-based management with a view to the long-term conservation of the archaeological heritage and the site's outstanding universal value.

UNDERWATER HERITAGE INSTITUTE

The Underwater Heritage Institute under the Ministry of Culture of Bulgaria is the national institution for underwater archaeology and a UNESCO Category 2 Centre. Based in Sozopol, it carries out archaeological research, documentation, conservation, training and public outreach. The Institute promotes international cooperation and supports the protection and sustainable management of underwater cultural heritage in Bulgaria, the Black Sea and the Lower Danube regions.



Aleta Guadelli is an archaeologist with a PhD in Prehistory and over 30 years of professional and field experience in Bulgaria, France and Peru. She has worked in cultural heritage conservation, management and digitisation, including as Chief Expert at the National Institute of Immovable Cultural Heritage (2019–2025). Since December 2025, she has been an archaeologist at the Underwater Heritage Institute. From 2022 to 2025, she represented Bulgaria on the UNESCO World Heritage Committee and from 2023 to August 2026 coordinated the Danube Limes nomination. She is also the author of the 'Atlas of Immovable Cultural Heritage'. Her research interests include prehistory, cave archaeology, GIS and spatial analysis.

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Digital Technologies for Protecting Montenegro's Underwater Cultural Heritage from Climate Threats

Darko Kovačević

The Centre of Archaeology forms part of the Institute for Interdisciplinary and Multidisciplinary Studies at the University of Montenegro in Podgorica. Our multidisciplinary team works along one of the Mediterranean's most dramatic coastlines, where steep limestone mountains descend almost directly into the Adriatic Sea. This narrow and rugged coastal zone has been used by seafarers, traders, and militaries for more than two millennia. Its seafloor preserves their traces in Hellenistic and Roman cargo ships, ancient and medieval ports, Austro-Hungarian and World War wrecks, as well as modern vessels lying side by side (Jurišić, 2000; Gačević, 2012). Our expertise lies at the intersection of archaeology, heritage management, and digital technology. The centre`s work extends beyond research to include documentation and data management, transforming hidden and difficult-to-access heritage into reliable information for public authorities, spatial planners, and the wider public.

Montenegro's narrow coastal zone leaves little space between the mountains and the sea, concentrating climate impacts within a particularly fragile strip of land and shallow water. Sea-level rise and coastal erosion are already recognised as major risks to exposed Mediterranean heritage (Kapsomenakis *et al*., 2023). Montenegro's steep mountain catchments further increase the vulnerability of coastal and shallow-water sites to flooding, sediment movement, and extreme events (Reimann *et al*., 2018). Storm waves can disturb sediments that protect archaeological remains, bury or expose objects, and damage structures that have survived for centuries (Howland and Thompson, 2024). Flash floods carry large quantities of sediment and debris directly into coastal and shallow-water areas (Bonacci *et al*., 2006). This is a recurring problem at the coastal archaeological area of Risan in Boka Kotorska Bay, where rainfall, steep terrain, and active hydrological and geological processes create severe risks. Flash floods, intensive sedimentation, groundwater flooding, and landslides are actively impacting the ancient remains, posing a major challenge to their preservation and study (Bajtler and Trusz, 2020; Kowal and Lemke, 2014). Risan illustrates how locally specific hydrological and geomorphological conditions can make archaeological sites highly sensitive to wider climatic change.

Projected climate drivers provide a clearer basis for distinguishing existing environmental pressures from the additional risks generated by climate change. Under the RCP8.5 scenario, Montenegro's Third National Communication projects that the number of summer and tropical days will increase by 100 per cent during 2011–2040, compared with the 1971–2000 reference period (Ministry of Sustainable Development and Tourism and UNDP 2020: 176). For the coastal area of Montenegro, projections based on two Med-CORDEX regional climate models indicate an increase in mean annual sea-surface temperature of 0.5–1.5°C in 2011–2040, 1–2°C in 2041–2070, and 2.5–3.5°C in 2071–2100, relative to the 1971–2000 mean, also under RCP8.5 (Ministry of Sustainable Development and Tourism and UNDP 2020: 179). Montenegro's Climate Change Adaptation Plan anticipates declining mean annual precipitation, particularly during summer: by the end of the century, annual precipitation is projected to decline by around 6 per cent under SSP2-4.5 and by up to 25 per cent under SSP5-8.5. Under SSP2-4.5, rainfall during

2040–2099 is projected to shift towards potentially wetter winters and drier summers (Ministry of Ecology, Sustainable Development and Northern Region Development of Montenegro 2025: 29–30). The Plan further identifies projected Adriatic Sea-level rise of approximately 35 cm by the end of the century (Ministry of Ecology, Sustainable Development and Northern Region Development of Montenegro 2025: 228).

These projections do not mean that all current deterioration of underwater heritage can be attributed to climate change. Anchoring, dredging, coastal construction, looting, pollution, and pre-existing hydrological and geomorphological instability remain independent pressures. Climate change is expected to amplify these existing pressures by raising the baseline for coastal inundation and erosion, modifying sediment dynamics, increasing the likelihood of drought–heavy-rainfall sequences that can mobilise sediment from steep catchments, and altering the thermal and ecological conditions in which submerged materials deteriorate (Bonacci *et al*., 2006; Ministry of Sustainable Development and Tourism and UNDP 2020: 176–179; Ministry of Ecology, Sustainable Development and Northern Region Development of Montenegro 2025: 29–30, 228). For management purposes, the key distinction is therefore between baseline site vulnerability, determined by material composition, depth, exposure, sediment regime and human activity, and climate-induced change in the frequency, intensity or spatial reach of the processes acting upon the site.

Projected sea-surface warming may, in particular, encourage the colonisation of wrecks by marine organisms and alter the deterioration pathways of organic and metallic materials (Vuong *et al*., 2023; Lord, 2017). This issue is especially relevant to the First and Second World War wrecks scattered along Montenegro's coast. Ocean acidification may place additional pressure on calcium-carbonate materials, including shells and biological deposits, although Montenegro-specific projections of marine carbonate chemistry remain limited. Changing marine conditions may also affect stone, ceramics and other archaeological materials (Fitzer *et al*., 2015). At the same time, projected sea-level rise is expected to alter patterns of flooding and erosion, placing additional pressure on shallow-water sites and coastal heritage that have developed a fragile balance with their environment over centuries (Germinario *et al*., 2025). These climate-related pressures compound pre-existing anthropogenic and environmental threats to underwater sites.

Through several European Union (EU) co-funded projects, we developed the infrastructure and specialist capacity that now support our current initiative, the Underwater Cultural Landscapes of Montenegro project. The project was launched to address a critical gap. Until recently, most underwater sites in Montenegro remained invisible to the government and institutions. A site that cannot be identified on a map cannot be legally protected, incorporated into coastal-development decisions, or monitored over time for climate-related damage (Kovačević, 2025). In-situ preservation and documentation therefore became our core principles. By documenting sites precisely where they lie, we preserve their archaeological context while making them visible to the institutions responsible for their protection (Gambin *et al*., 2021).

To achieve this, we combine acoustic, optical, and satellite-based remote-sensing methods, each responding to a different documentation requirement. Multibeam echo sounders and side-scan sonar, deployed from a research vessel, produce high-resolution 3D and 2D maps of the seabed (**Fig. 1** and **Fig. 2**). These methods allow us to understand a shipwreck's form and immediate surroundings, even in deep or turbid water, without physical contact (Papatheodorou *et al*., 2011). Where sites lie beyond safe diving depths, or where an initial visual assessment is required before deploying divers, we use a remotely operated vehicle (ROV) to inspect wrecks and record video footage. This extends our capacity to investigate deeper or more hazardous parts of the seabed (Foley and Mindell, 2002).

For sites requiring finer detail within diveable depths, divers undertake underwater photogrammetry (**Fig. 3**), capturing thousands of overlapping photographs that are processed into photo-realistic 3D models with high resolution and accuracy (Calantropio and Chiabrando, 2024). On land, we complement this work with satellite imagery to monitor coastal sites threatened by erosion and storm inundation. This allows us to track shoreline retreat, land-cover change, and inundation patterns across extensive stretches of coast that would be impractical to survey solely from the ground

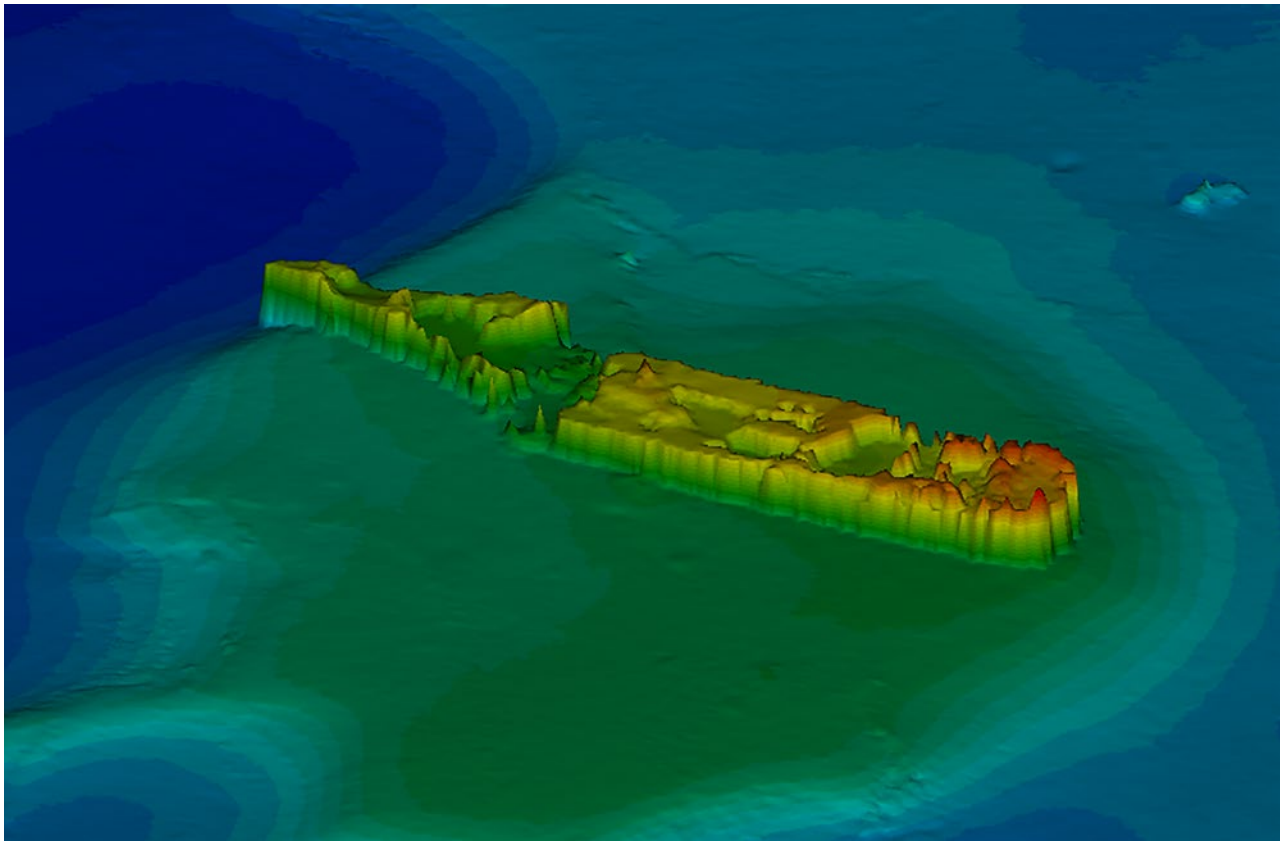


Figure 1- Remains of the Royal yacht "Rumija" (author Luka Calic © UoM).

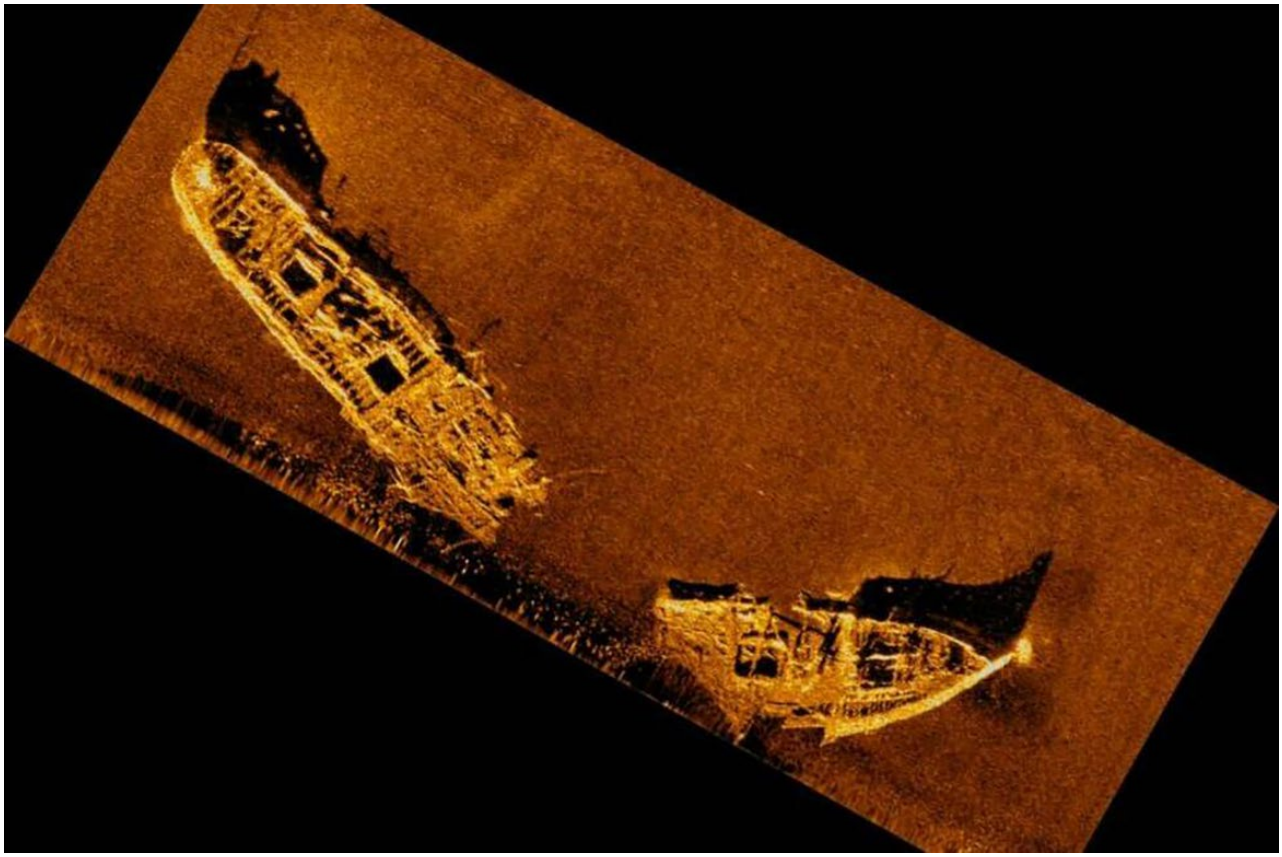


Figure 2- The Goritia mixed cargo steamship of the Austrian Lloyd sunk in the vicinity of Ulcinj (author Luka Calic © UoM).



Figure 3- Divers are preparing a site for photogrammetry survey (author Antonio Lagudi © UoM).

(Elfadaly *et al*., 2023). Where a coastal site requires more detailed, object-level recording, we deploy drones for airborne photogrammetry. This applies the same high level of resolution and accuracy modelling approach used underwater, ensuring that marine and terrestrial heritage are documented through a consistent and comparable methodology across the land-sea interface (Graham, 2025).

All datasets, whether generated by sonar, ROV footage, underwater and airborne photogrammetry, or satellite imagery, are consolidated within a centralised Geographic Information System governed by standardised metadata protocols (Figueiredo and Bernardes, 2014). This integration brings together five distinct data streams, each suited to a different depth, scale, or level of detail, into one coherent digital record for every site (Spreafico *et al*., 2024). Heritage authorities, spatial planners, and researchers can therefore use the same reliable and interoperable information, regardless of the technology originally used to capture it. This transforms isolated survey results into a unified basis for legal protection, long-term monitoring, and evidence-based coastal planning (Kovačević, 2025).

This approach has documented a substantial proportion of currently known sites, ranging from Hellenistic and Roman maritime activity to twentieth-century conflict heritage. These include the Austro-Hungarian cruiser SMS Zenta near Petrovac, the royal yacht Rumija in Bar, other First and Second World War wrecks, and the remains of a Supermarine Spitfire off Herceg Novi. Integrated into a centralised GIS inventory, these data have informed competent authorities and contributed to Montenegro's Spatial Plan up to 2040. This formally embeds underwater heritage within national planning and supports its protection alongside tourism, fishing, and marine infrastructure (Kovačević, 2025).

At the Center of Archaeology, we consider visibility to be the essential first response to threats that remain hidden beneath the sea. Precise and repeatable digital records allow us to revisit sites at regular intervals, compare their condition, and identify or quantify, where survey resolution and repeatability permit, material loss, sediment

movement and the progression of erosion. The centralised GIS database gives this documentation practical value. It enables heritage authorities to recognise underwater cultural zones early in maritime spatial planning, before conflicts emerge with development, tourism projects, or fishing activity (Figueiredo and Bernardes, 2014). This approach corresponds with the international direction set out in UNESCO's 2025 White Paper on Underwater Cultural Heritage, Climate Change Adaptation and Mitigation, which calls for detailed resource documentation, area-based vulnerability assessments, and the integration of underwater cultural and natural heritage into national climate-adaptation planning (Breen, 2025). Our work is being aligned with these recommendations and with the EU Maritime Spatial Planning Directive.

Looking ahead, our priority is to establish regular monitoring cycles, secure long-term support through EU programmes, and strengthen cooperation with regional and international partners. These steps will help ensure that Montenegro's underwater cultural heritage is not treated as an invisible archaeological resource, but as a documented and manageable part of the country's climate-resilient coastal landscape.

UCG
Univerzitet Crne Gore

The Centre of Archaeology of the Institute for Interdisciplinary and Multidisciplinary Studies, University of Montenegro, advances terrestrial and underwater heritage through digital innovation and interdisciplinary research. From project development to implementation, we safeguard cultural heritage legacy, bridging theory and practice to preserve our shared past for future generations.



Darko Kovačević

Darko Kovačević studied history in Novi Sad, Serbia, and maritime archaeology and underwater cultural heritage in Alexandria, Egypt, where his interest in the Middle East developed into a research focus. His fieldwork has taken him across Turkey, Syria, Lebanon, Israel, Egypt, Greece, Croatia, and Malta. At Heritage Malta, he contributed to an innovative underawater museum system and its management unit. He later brought this experience to Montenegro, adapting digital interpretation methods to the protection and presentation of submerged heritage. He founded the Center for Archaeology at the University of Montenegro, dedicated to mapping, documenting, and interpreting heritage preserved beneath the sea and land. His current work combines project development with research into heritage governance, accessibility, and management. His approach views underwater cultural heritage not only as a record of the past, but as a resource for understanding environmental change, strengthening resilience, and fostering cultural dialogue.

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Riverine heritage in the changing environment of the Middle Danube Basin, Hungary

Attila J. Tóth

During the summer of 2026, the rivers in Hungary have been recorded at their lowest level since scientific records began more than a century ago. The region's main river is the Danube, which has one of Europe's largest catchment areas and links the northern Alps to the Black Sea, connecting important economic and cultural regions. During the periods of low water levels, large areas of the riverbed were exposed, primarily in the vicinity of gravel banks and islands. This article We would I examine three aspects that are closely linked to this weather anomaly.

The sections of the riverbed that had dried out or were covered with shallow, clear water provided ideal conditions for surveying new sites and for monitoring and documenting known locations. Whereas previously, we had carried out surveys using side-scan sonar, or conducted exploratory dives in strong currents with limited visibility, we were now able to directly observe areas that had previously been covered by as much as 1–2 metres of water. Community archaeology has developed significantly over the last decade, involving civilians in archaeological research; most commonly, volunteers with metal detectors assisting museums. As there is no central institution in Hungary with an adequate budget to undertake the protection and research of underwater cultural heritage (UCH), we carried out the fieldwork within the framework of museum collaborations, often based on and with the assistance from participants in community archaeology programmes. Among the good examples, a highlight was the collaboration between the Árpád Museum in Ráckeve and the Károly Viski Museum in Kalocsa. As a result of these collaborations, we identified a medieval stone-and-beam structure on Paks Island, located on the outskirts of Dunaszentbenedek thought to be a monumental structure associated with giant sturgeon fishing, as well as the wreck of a medieval wooden ship. The latter was built using the extended monoxyl technique, made of oak and fastened with treenails (**Fig. 1**). In this case, the low water level clearly aided the archaeological research.

The second consideration relates to the negative effects of low water levels. High temperatures and strong sunlight causing damage to the wooden remains. Where possible, we covered the remains with a thin layer of sediment (gravel or sand), as we found that even a covering of just a few millimetres



Figure 1- An overview of the shipwreck at Dunaszentbenedek.

helps to helps to retain the moisture in the wood and save it from exposure to UV radiation. In our previous study (Tóth 2020), which examined the low water levels of 2018, we highlighted anthropogenic impacts. By 2026, the destruction caused by human activity had surpassed all previously observed negative phenomena. Crowds flooded the Danube, particularly along the urban stretches (including Budapest). The majority of people behaved as visitors, merely observing and taking photographs; several reports were received from such visitors. However, there were also large numbers of people who began to alter the riverbed; it was not uncommon for them to rearrange objects (building small towers from the stone remains of buildings) or to take artefacts; in some cases, we observed deliberate vandalism. Near Dunaújváros, in the vicinity of Szalki Island, we recorded a medieval timber-and-stone structure, which we had investigated on several occasions in previous years. The interior of the oak beam framework had been filled with limestone "blocks" from a Roman Period settlement that had stood on the riverbank (**Fig. 2**). Illegal collectors had displaced stones across a large area and in large quantities, and also stole several Roman stone carvings. Uninvited volunteers, acting with good intentions but without the necessary expertise excavated several sculptured stone artefacts without first documenting them, and then donated them to the local museum. The police, the local council, the museum and the regional heritage protection office were unable to manage the situation. The integrity of sites had been violated, and the excavated stone artefacts, having been exposed to the dry air, are deteriorating, a situation the museum is currently unable to address.

We have also received several reports that different museum's volunteers using metal detectors organised 'expeditions' into riverbeds without authorisation or expertise, retrieved isolated objects from there, and then donated them to museums. Although the artefacts in these cases have entered public collections, the issue of their conservation remains unresolved, and we have lost the opportunity for scientific field observation.



Figure. 2- Detail of a stone and timber structure near Dunaújváros.

The third consideration is the question of the historical context. The stones and wooden pile structures found in the riverbed are often situated from the modern shoreline towards the riverbed, and are aligned with the most recent low water level[1]. These sites typically date from the Roman period (Tóth 2011) or are associated with the 12th–13th centuries AD. We believe that this is not a coincidental phenomenon but may be linked to the warm climatic periods of the Roman and Medieval eras. The mid- and long-term hydrological climate change impact modelling study using the mechanistic hydrological model PROMET pointed out the problem of declining summer rainfall in the future, which will cause low water levels in the Danube river Basin (Probst and Mause 2023).

The so-called 'Little Ice Age', which occurred during the late Middle Ages and Early Modern Period, has also left a significant mark on the archaeological record. From our research area, along the extensive Csepel Island in the Danube, the former medieval villages of Lacháza and Pereg moved to higher ground further away from the river between the 1740s and 1770s AD due to frequent flooding. This process is well documented by a series of hand-drawn maps produced during that period (**Fig. 3**). The case of the village of Čunovo in Slovakia was endangered by Danube river erosion during the 1780-1790 AD period (Pišút 2008) could be mentioned as an analogy. The study of the historical flood records of the Viennese Danube River pointed out that 36 floods were documented between 1768 and 1789 (Hohensinner, Hahmann 2020). Measured data for historical floods and low water levels are mostly documented since the Renaissance in Europe (Brázdil 2012). Changes to the river channels were also decisive in terms of the location of fishing spots, mill sites and fords, and thus may have left their mark on the archaeological record. The use of the archaeological data is still scarce in river historical research along the Middle Danube Basin (Tóth 2008, Vadas 2013), and this is why the underwater archaeological research accompanied by interdisciplinary cooperation will have high potential.

Along the southern shores of Csepel Island, between Dömsöd and Makád, the riverbed is currently blocked by a sluice gate. However, we were able to observe a shallow strip crossing the riverbed that stood out from its surroundings during bathymetric and sonar surveys. This area may have functioned as a ford during periods of low water levels in the Danube. From a scientific perspective, we consider it important that as archaeologists at the Árpád Museum, we are able to study not only the waters around the island but also the topography of the surrounding land areas; this enables the joint investigation of sites located both in the water and on the riverbanks. The sites identified on the shore are concentrated in the area of the presumed ford (**Fig. 4**); the proportion of imported artefacts in the surface finds from this area is high, suggesting significant connectivity. From the 17th century AD onwards, finds became less frequent, and from the 18th century AD onwards settlement ceased; this can be explained not only by historical processes but also by the higher water levels during the

1- The top of the stone and timber constructions emerged to surface of the river at Dunaújváros, Szalki Island and at Dunaszentbenedek, Paksi Island at 20 cm of the Budapest water gauge, where the „lowest water level" is set to 33 cm.



Figure 3- Details from 18th-century manuscript maps showing the „migration" of the settlements of Lacháza and Pereg.

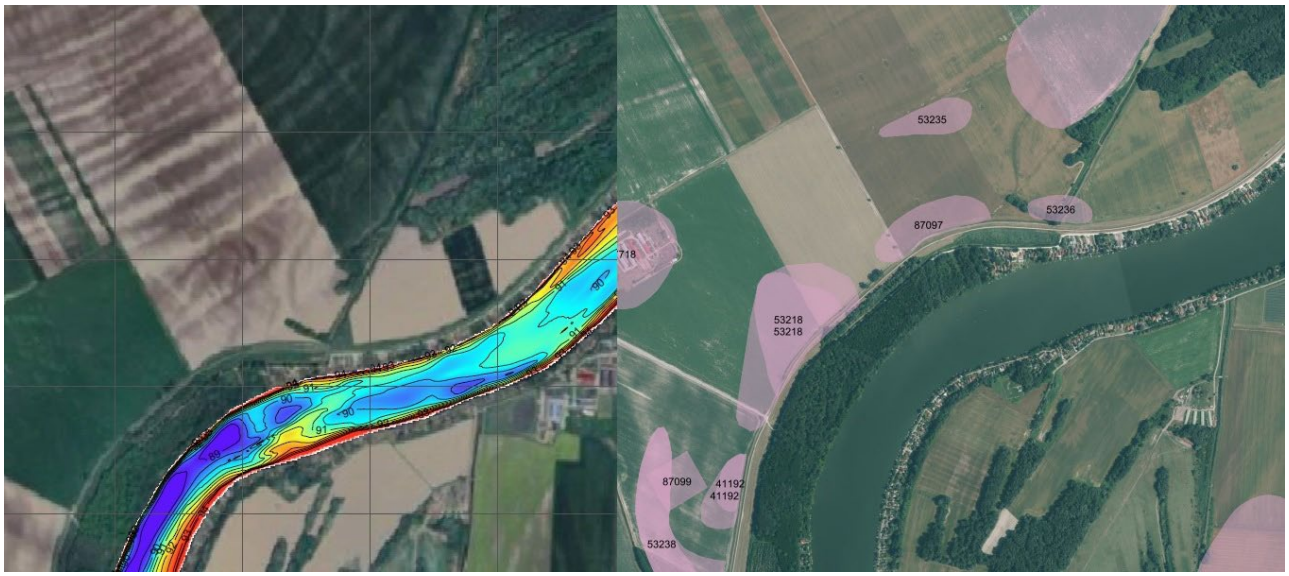


Figure 4- Location of the presumed ford, showing archaeological sites between Makád and Dömsöd.

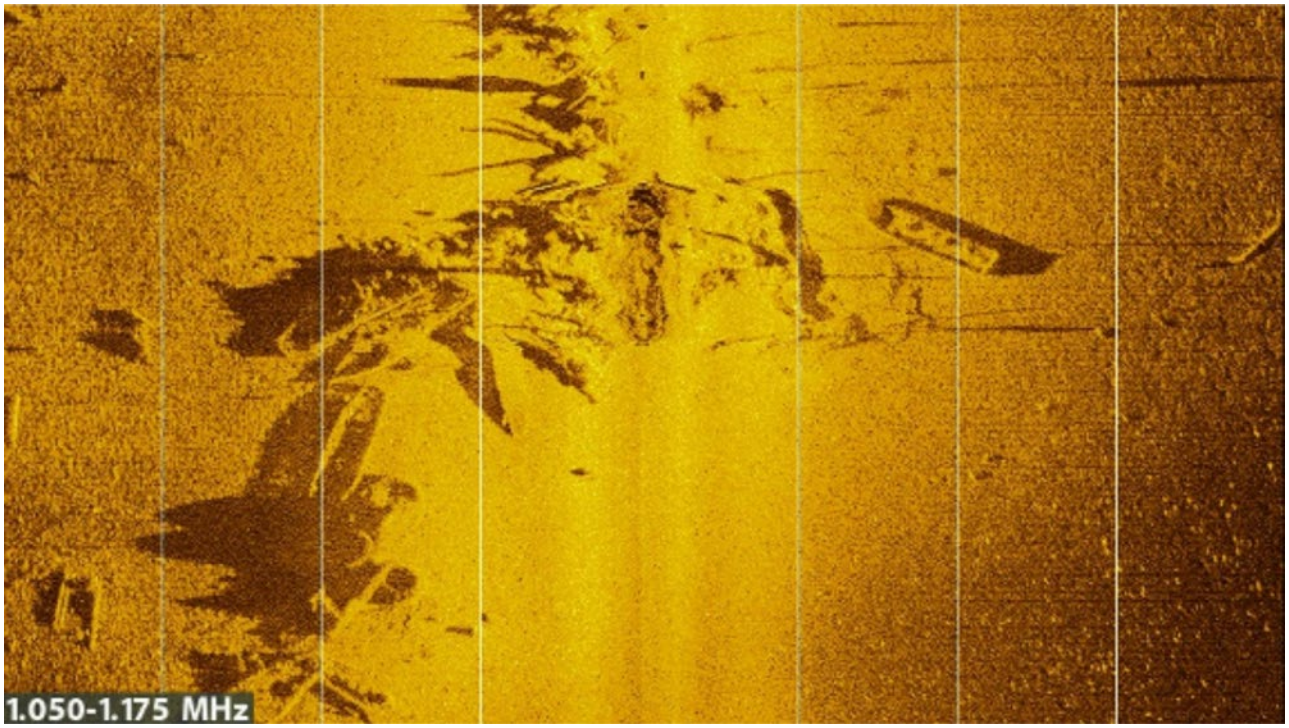


Figure 5- Sonar image of features found at the presumed ford.

Little Ice Age resulting in decline in the usability of the ford. During a side-scan sonar survey of the riverbed, we detected the remains of several boats and ships clustered at the upper edge of the ford; we are planning further investigations there (**Fig. 5**). The investigation of riverine sites and the documentation of changes in their condition demonstrate that climate change offers only minimal benefits to research; however, changes to the natural environment – particularly where these are associated with anthropogenic influences – pose a significant threat to underwater heritage, in some cases threatening its ultimate destruction, and, moreover, without any record being made of it.

The Árpád Museum is a so-called territorial museum in Hungary, responsible for the South half of the Csepel Island, 40 km from Budapest. The museum collects all types of archaeological material, and in cooperatively participates in underwater research in the territory of partner museums in Hungary and in international cooperations abroad, principally in riverine.



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Protection of Underwater Cultural Heritage in Croatia

Mladen Pešić

Underwater archaeology made significant advances in Croatia at the beginning of the 21st century CE, establishing a quality control system of archaeological surveying, investigation and protection of underwater archaeological sites and finds.

More than 600 underwater sites have been registered in Croatia. At the moment, 184 sites and areas are permanently protected in the Register of Cultural Goods of the Republic of Croatia. There are 36 sites or areas in Croatia where diving is permitted for tourists and visitors. Diving on these sites is regulated by permissions, prohibitions and obligations for the concessionaires who are allowed to take visitors to the underwater sites.
The concessionaires are diving centres that pay an annual fee to the Ministry of Culture and Media. Concessionaires receive a five-year license and have permission to take visitors to the accredited sites. Diving centres are held responsible for the protection of sites and are responsible for preventing any damage or disturbances of the cultural heritage. Concessionaires are required to inform the Ministry about any activity that has negatively impacted a protected site.



Figure 1- Part of the roman lead anchor from the 1st century AD, shipwreck Letavica on the island Pag (photo: M. Pešić).

The Ninth Session of the States Parties to the 2001 Convention held in Paris from June 13 to 14, 2023 accepted the Croatian proposal “System of protection and management of underwater cultural heritage on sites, including Velika shallows near Cavtat, Letavica and Baron Gautsch” which was designated as UNESCO example of best practice in UCH (**Fig. 1, 2, 3**).

The system is designed to be non-intrusive and should not damage the site, but remain removable, if necessary, as the possibility for future archaeological excavation of a site. All 36 sites and zones that are within the system of concessions are preserved *in situ*. This system helps to finance underwater archaeology, increases benefits for the local community by enabling new diving destinations, and extends what dive centres can offer. It also permits more fragile sites to be open to the public without compromising their protection. The importance of this kind of *in situ* protection,



Figure 2- Shipwreck with Roman North African amphorae at Cavtat (photo: M. Pešić).



Figure 3- Baron Gautsch, 1914. wreck near Rovinj Cavtat (photo: I. Vidulić).

in line with the UNESCO 2001 Convention, lies in the preservation of cultural objects and the use of underwater archaeological sites for presentation and tourism. Protected sites have become an excellent destination for diving tourism, which is recognized by the local population who take advantage from this fact in various ways. In such a manner, the locals, along with diving centres, become the best guardians of the site.

Regular visits to the protected sites by the diving centres and the guided groups that they take, can be helpful in long term monitoring of the sites. Although these sites are periodically visited by the archaeologists, during tourist season some of the protected sites are visited by the diving centres almost on a daily basis. In a long-term protection model this is helpful because all possible changes caused by climate change can be monitored and noticed almost immediately. In some cases, it has been noticed that the typology of organisms that live on the archaeological wrecks has changed: that new species have been introduced.

Over the last few years ICUA has developed a set of diverse course models with a rich international component which facilitate the development of long-term links between institutions and individuals engaged in developing the protection of UCH in their countries. In 2024, ICUA Zadar developed and established training for In-situ Conservation of Underwater Metal Heritage, focusing on the degradation of modern wrecks in underwater environments. This new training program provides intensive workshops to familiarize conservators and archaeologists with in-situ corrosion studies on numerous metal shipwrecks and World War II aluminium alloy, frequently found on aircraft located in the Adriatic Sea. Marine corrosion, wreck monitoring, and cathodic protection are some of the topics covered in theoretical courses that are applied in practical exercises on three different wrecks in the Adriatic Sea. One of the main case studies was the protection of the wreck of a Junkers Ju 87 R-2, the Stuka, which was discovered off the southern coast of Žirje Island, in the Šibenik archipelago (**Fig 4**). Although previous assessments had suggested that the wreck was in relatively good and coherent condition, the 2024 survey revealed significant corrosion, including numerous small, irregular perforations across the fuselage caused by pitting corrosion (Pinjušić 2026). Corrosion is affected mainly by the depth, sea water temperature and oxygen percentage. We know that in Adriatic Sea water temperature is increasingly rising round 0.03-0.05°C per year and as a part of the Mediterranean Sea, it has been noticed that many marine heatwaves that occur regularly, certainly can affect and disturb conditions on the wrecks (Neri et all. 2025; Hamdeno Alvera-Azcaráte 2023). Even though some of these changes cannot be seen in yearly monitoring of the sites, they certainly cause changes in deterioration



Figure 4- Diving at the site of a downed Stuka warplane during the course (photo: R. Surić).

of the sites that are exposed to them. While these seemingly small changes in temperature are not necessarily noticeable to divers and tourists that visit these sites, some of the environmental changes can be observed over prolonged periods. During our multiannual research, we have noticed new invasive species that several years ago were not perceived to exist in the Adriatic, but now, they have found their home on protected wrecks. Such a species is lionfish that can be regularly seen in the Adriatic.



Figure 5- Visitors with 360 glasses at ICUA Education and presentation centre St Nicholas (photo: F. Brala).

In order to promote the importance of protecting UCH and making it more accessible to the public, ICUA Zadar implemented the project “Renovation of the former church and monastery of St. Nicholas in Zadar”, co-financed with funds from the European Funds for Regional Development within the Operational Program. Through displayed archaeological exhibits, visitors can discover the richness of Croatia’s submerged heritage (**Fig. 5**). The permanent exhibition is enhanced with virtual content, tactile screens, and VR glasses, offering an interactive and engaging insight into the fascinating world of underwater archaeology bit also stresses the sea level change and effects of climate change during the history of mankind.

The International Centre for Underwater Archaeology in Zadar (ICUA Zadar) became a separate legal entity in 2009 when it saw signing of an international agreement between UNESCO and Croatia covering the scope of ICUA activity. Since then, operating as the UNESCO category 2 center, develops different programme activities. ICUA's core tasks are to conduct activities and education in the fields of research, conservation and restoration and the promotion of underwater cultural heritage, disseminating the methods of investigation in underwater archaeology, conservation and restoration, training and the exchange of knowledge, as well as promotion of UNESCO's 2001 Convention.



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Climate change and Cultural Heritage: Identifying and monitoring emerging challenges in coastal and underwater heritage (Italy).

Castagnino Berlinghieri E.F, Monaco C., and *Antonioli F.*

Introduction

Among the multiple hazards affecting archaeological sites in coastal areas, climate change and projected sea level rise, represents an increasingly significant threat to the conservation of cultural heritage. Even modest increases in relative sea level will require the development of flooding-hazard scenarios, since it would cause substantial negative consequences at archaeological sites situated close to the present-day shoreline or at elevations only slightly above current sea level. This potentially increases their exposure to extensive coastal inundation, shoreline retreat, erosion, and storm-related flooding. Coastal archaeological heritage is therefore particularly sensitive to the cumulative effects of gradual environmental change and extreme events, whose impacts may progressively compromise the integrity, accessibility, and long-term preservation of archaeological remains (Castagnino Berlinghieri, Antonioli and Bailey, 2020). Certain sites, in areas of small tidal range, require a precisely defined relationship to sea level at the time of construction and can provide significant information on relative sea level change during the last millennia (Auriemma and Solinas, 2009). However, along Mediterranean shores in particular, the increasing sophistication of human development has led to there being a variety and adequate number of archaeological remains that can be used to establish constraints on relative sea level (Flemming, 1969). For this reason, to assess the potential flooding of selected archaeological structures (quarries, tombs and slipways) located in eastern Sicily we combined the IPCC projected sea-level rise (SLR) for 2100 with the local vertical coastal land movement rates provided by the Copernicus Sentinel-1 European Ground Motion Service (EGMS).

Climate Hazards and Cultural Heritage Risks: insights from selected case studies

In order to have the most complete risk scenario possible, we selected three archaeological sites of the last 3500 years (Naxos, Ognina, Marzamemi) from eastern Sicily (**Fig. 1**), one of the most active tectonic areas of the Mediterranean basin. In this area, even if significantly uneven from a tectonic point of view, the expected SLR in the next few years could be a potential cause of significant land flooding and morphological changes of the coastal strip. At these sites, even a relatively small rise in relative sea level may result in extensive coastal inundation.

For the assessment of potential coastal flooding of the selected sites, over the next 74 years, i.e. from 2026 to 2100, we considered the most recent projections provided by the IPCC Intergovernmental Panel on Climate Change) Sixth Assessment Report (AR6, IPCC, 2021), bearing in mind that the IPCC projections represent global mean sea-level change (i.e., the eustatic component), to which local vertical land movements associated with glacial isostatic adjustment (GIA) and tectonic processes must be added. Under the very-high-emissions scenario SSP5-8.5, IPCC projects a likely global mean SLR of 0.63–1.01 m by 2100, with a median estimate of approximately 0.77 m, relative to the 1995–2014 baseline period (IPCC, 2021). For the flooding calculations presented in this study, we therefore considered the lower and upper bounds of the IPCC likely range, namely +0.63 m and +1.01 m, respectively. The estimate of present-day vertical ground motion (positive or negative, expressed in mm yr^{-} and corrected according to the methodology proposed by Cardello *et al*. (2025), is provided by the Copernicus Sentinel-1 European Ground Motion

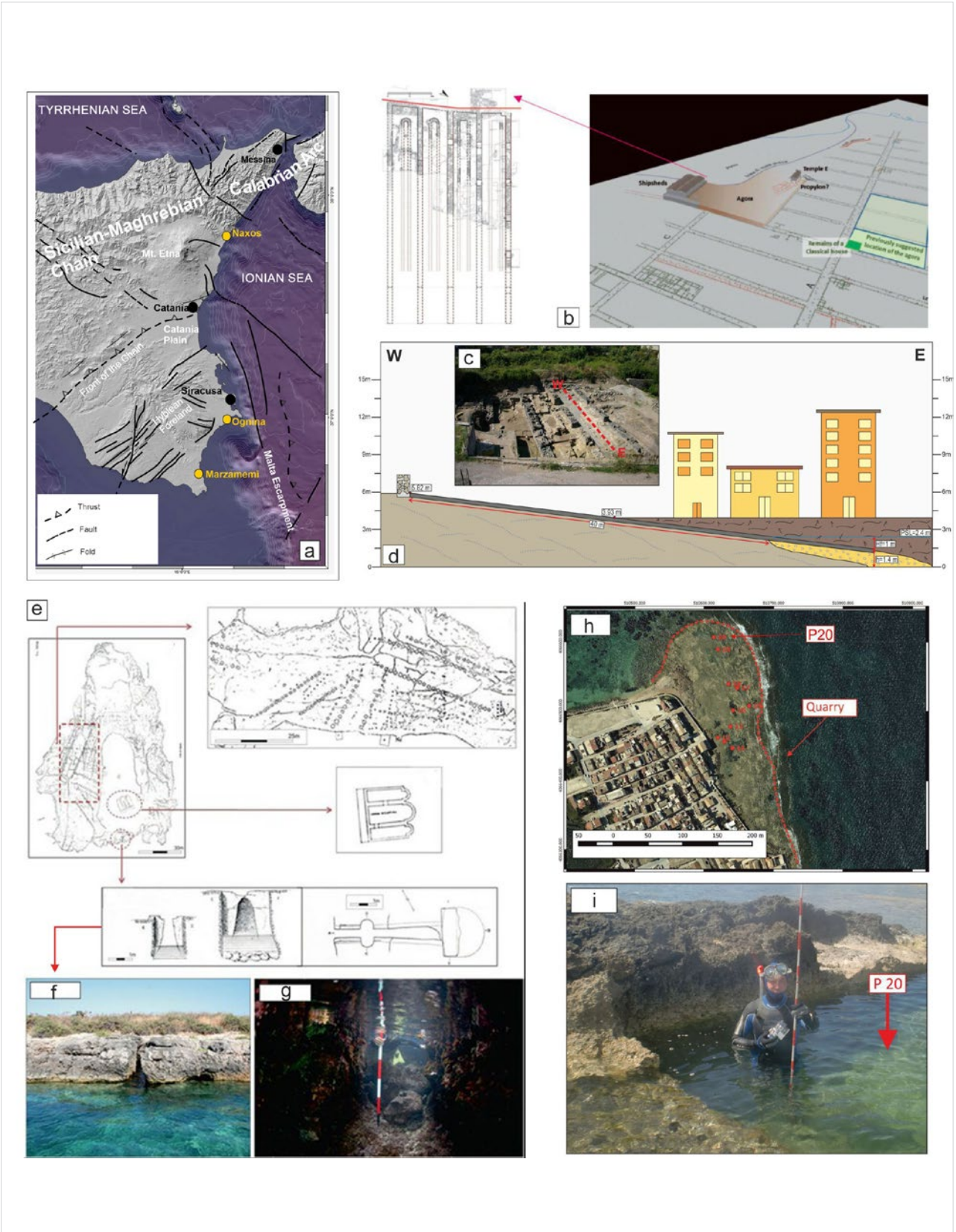


*Figure 1- (a) Tectonic scheme of eastern Sicily and geographical position of the studied sites along the Ionian coast of Sicily. (b) The shipshed complex of Naxos and their 3D reconstruction in relation to the presumed ancient coastline (in blue) and the Archaic Stree**t al**ignment of the town (from Lentini **et al.**, 2015, modified). (c) View of the shipsheds complex. (d) Longitudinal transect of a slipway, with inferred reconstruction of the portion below the modern buildings (from Spampinato **et al.**, 2012, modified). (e) Archaeological remains on the island of Ognina (adapted from Bernabò Brea, 1966). (f) Entrance to a submerged long rock cut dromos of a Bronze-age chamber tomb. (g) Direct survey of the tomb (from Scicchitano **et al.**, 2008). (h) Google Earth detail of the ancient Greek quarry of Marzamemi. (i) View of the northernmost sector of the quarry where the depth of the floor was measured (see h for location).*

Service (EGMS: https://egms.land.copernicus.eu/), which covers the most recent approximately six-year period. Unlike estimates based on geological and archaeological markers, EGMS-derived rates integrate the combined effects of the processes described above, including tectonic, isostatic, and other components of vertical ground motion.

In northeastern Sicily, located at the southern edge of the Calabrian Arc (Fig. 1), uplifted archaeological and geomorphological markers indicate that in the last 2,500 years ago, tectonic uplift was faster than SLR. The Naxos marker, ~ 2300 years old (Blackman and Lentini, 2003; Lentini, Blackman and Pakkanen, 2013), is currently located at +1.40 m above present mean sea level (Spampinato *et al*., 2012), suggesting a high uplift rate related to regional tectonic processes (Antonioli *et al*., 2006). Accordingly, EGMS measurements suggest an uplift rate of 1.70 mm/yr. In southeastern Sicily, the archaeological markers at Ognina, ~ 3400 years old (Bernabò-Brea, 1966; Castagnino Berlinghieri, 1993-1995) and Marzamemi, ~2600 years old (Idà, 2025), are already 1.21 m and 1.34 m respectively, below present mean sea level (Scicchitano *et al*., 2008; Monaco *et al*., 2020). Submerged markers indicate that in the last 4 ,000 years, SLR was faster than tectonic uplifting, since this area is tectonically stable (Antonioli *et al*., 2006). It's worth noting that the EGMS measurements indicate for both Ognina and Marzamemi areas a slight subsidence (-0.60 mm/yr) in the last decade. This recent and marked change in crustal vertical motion has been linked to regional interseismic tectonic processes (Cardello *et al*., 2025 and references therein) and could worsen predictions.

Discussion and Conclusions

When the projected IPCC AR6 SLR is combined with the local vertical-motion components (GIA and vertical tectonic), the resulting relative sea-level change by 2100 varies substantially among the three sites. Under the minimum and maximum IPCC SSP5-8.5 likely projections, the calculated relative sea-level rise ranges approximately from 0.50 to 0.88 m at Naxos, from 0.65 to 1.05 m at Ognina, and from 0.67 to 1.05 m at Marzamemi. The results illustrate the sensitivity of future relative sea-level estimates to the temporal scale of the vertical-motion component. In particular, the strong tectonic uplift at Naxos substantially compensates for both the projected eustatic sea-level rise and the ongoing GIA-related relative sea-level rise. By contrast, the near-stable conditions at Ognina and Marzamemi provide much less compensation, while the recent subsidence detected by EGMS further increases the projected relative SLR at both sites. Our estimates indicate that the Naxos site remains above the projected relative sea level under all combinations of the IPCC AR6 likely range and local vertical-motion estimates. The markers at Ognina and Marzamemi are already below present mean sea level and therefore represent a different situation: their future vulnerability is associated not with an initially emergent archaeological structure becoming submerged, but with the progressive increase in relative sea level affecting already submerged archaeological remains.

These results emphasize that future coastal relative sea-level assessments should not rely on a single vertical-motion process, and for this reason they should integrate geological, archaeological, and geodetic observations. Building on this interdisciplinary perspective, the approach proposed here can be extended to other coastal and underwater heritage contexts beyond Italy. Continuous monitoring should not be understood as an end in itself, but as a dynamic tool to identify emerging risks, prioritize vulnerable archaeological sites, and guide the allocation of resources and urgent interventions. In this context, safeguarding archaeological heritage is particularly crucial, as coastal and underwater archaeological sites represent irreplaceable records of past human activity, environmental change, and long-term interactions between societies and coastal landscapes. Their protection therefore extends beyond the preservation of physical remains, contributing to the conservation of historical knowledge, cultural identity, and scientific evidence for understanding both past and future coastal change.

CENTRO UNIVERSITARIO EUROPEO PER I BENI CULTURALI

The European University Centre for Cultural Heritage (CUEBC) was established in Ravello in 1983 at the initiative of the Italian Parliamentary Delegation to the Council of Europe, under the auspices of the Council's Secretary General and the Italian Government. The CUEBC promotes interdisciplinary research, education and international cooperation in cultural heritage across the Euro-Mediterranean region. Its activities encompass the study, protection, and enhancement of tangible and intangible heritage, including maritime and underwater cultural heritage. Since 2024, CUEBC has been a member of the UNESCO UNITWIN Network for Underwater Archaeology, strengthening international research and cooperation in this field.



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Geologist, former Research Director at ENEA and Associate Researcher at the CNR, he has been working in coastal geomorphology for over 30 years, with a particular focus on relative sea-level changes. He has authored more than 175 publications in international peer-reviewed journals.

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The early field of interest was represented by studies on structural and regional geology with the production of several geological maps both in Southern Apennines and Sicily. Successively, researches have been turned to morphotectonics and active tectonics, aimed both to identify and characterize the main Quaternary faults of Calabria, Sicily and Crete (Greece), and to study Pleistocene marine terraces and Holocene paleaoshorelines. The research has been also focused to geo-archaeology of archaeological sites in Sicily Calabria and Crete, and on factors of geological risk along coastal areas of central Mediterranean, related to sea-level rise and tsunami waves.

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Climate Change and Italian Underwater Cultural Heritage: The Grado 6 and Lazise Shipwrecks as Contrasting Case Studies

Massimo Capulli

Introduction

This article examines the effects of climate change on Italy's underwater cultural heritage. Owing to its geographical configuration and the diversity of its aquatic environments, Italy presents a wide range of situations in which climatic transformations directly influence the conservation of submerged archaeological sites. This variety is further enhanced by the nature of the territory itself, which combines lagoon coasts, exposed marine stretches, deep lacustrine basins and aquatic systems governed by markedly different dynamics. Such complexity makes the Italian context a privileged observatory for unåderstanding how climatic impacts articulate at the local scale.

Within this framework, the selection of Grado 6 and Lazise (**Fig. 1**) relies on their profound environmental and chronological diversity. Juxtaposing such distinct contexts highlights that climate change is not a uniform global phenomenon, but the sum of localized processes that manifest according to specific environmental conditions. Rather than a mere descriptive exercise, comparing these contrasting sites provides an analytical lens to assess diverse risk profiles and refine tailored monitoring protocols.

Two Contrasting Case Studies

The contrast between Grado 6 and Lazise revolves around two fundamental parameters: chronology and depositional setting. Although both wrecks share the wooden nature of their hulls, they belong to construction traditions, original functions, and chronological horizons that are profoundly different. The Grado 6 Roman wreck, dated between the third and fourth century AD on the basis of radiocarbon analysis, reflects the techniques and solutions adopted in Mediterranean shipbuilding during the imperial period, with a conception of the hull linked to commercial navigation and transport needs (Capulli 2023a). The Lazise vessel, sunk in 1509, is instead a warship rooted in the Venetian fifteenth-century tradition (Capulli 2003). These chronological and functional differences define a first dimension of contrast between the two sites. Alongside this, a more significant one emerges, tied to their respective depositional settings, which belong to water systems governed by radically different physical dynamics. The Grado 6 wreck lies in a shallow lagoon environment, governed by typical hydrodynamic exchange processes of coastal lagoons (Kjerfve, Magill 1989), whereas the Lazise wreck belongs to the lacustrine context of Lake Garda: two water systems with structural characteristics and dynamics that differ in fundamental ways.

The northern sector of the Adriatic Sea is characterized by low-lying coasts and extensive lagoon systems shaped by the interaction of semidiurnal tides, fluvial inputs, and coastal sedimentation.[1] Within this framework lies the Grado lagoon, a shallow brackish environment separated from the sea by barrier islands and connected to it through tidal inlets. Water circulation is controlled by the tides, which in this part of the Adriatic reach unusually high amplitudes, producing stronger currents near the inlets and weaker ones in the inner basins. Salinity varies according to the balance between marine inflow and continental freshwater, while water transparency is influenced by suspended fine sediments and wind-induced mixing. The reduced bathymetry, with depths



Figure 1- General location of the study areas: on the left, Garda Lake with an arrow indicating the Lazise Shipwreck; on the right, the Grado–Marano Lagoon with an arrow indicating the Grado 6 Shipwreck (Created by author; background: ESRI Shaded Relief).

ranging from one to a few metres, favours the formation and periodic emergence of tidal flats and salt-marsh features, which are widespread in the Grado system.

In a completely different morphological context, Lake Garda is instead a large alpine basin of glacial origin. Located in northern Italy, it occupies a morphostructural depression shaped by the interplay between Neogene tectonics and Pleistocene glacial excavation. The central-northern sector is the deepest, reaching 350 m, with U-shaped cross-sections typical of glacial valleys, while the southern areas display shallower depths and gentler morphologies influenced by tectonic structures and morainic accumulations.

The fresh-water of Lake Garda is characterized by marked thermal stratification, with deep-water temperatures remaining stable throughout the year (Capulli 2021). Internal circulation is weak and largely driven by local winds, while water transparency is high due to the limited presence of suspended sediments. The overall configuration of the basin thus reflects a complex history in which the final glacial morphology inherits older tectonic lineaments and shapes the distribution of sediments and the present-day dynamics of the lake.

This preliminary distinction clarifies the framework within which Grado 6 and Lazise are situated, and allows the detailed presentation of the two sites with an awareness of the differences that define their contrast.

The Case of the Grado 6 Shipwreck

The Grado 6 shipwreck lies within the lagoon of the same name, at a depth between 3.5 and 5 metres, along the northern bank of the Litoranea Veneta,

in the stretch where this canal runs south of the island of Pampagnola, immediately adjacent to the Fòsa di Grado, one of the six tidal inlets connecting the lagoon to the Adriatic Sea. This is a highly dynamic environment, governed by tidal currents that in this sector of the Adriatic reach unusually high amplitudes, with daily flow reversals and rapid variations in hydrodynamic energy. Nevertheless, the predominantly clayey nature of the sediment ensured the preservation of the wooden hull structure for centuries.

The discovery of the shipwreck in July 2022 occurred during an inspection of submerged sites planned by the Carabinieri's Cultural Heritage Protection Unit (Capulli 2023a). This was synchronised with the competent Soprintendenza, made possible by an erosion phenomenon affecting the lagoon bank: several timbers were emerging from the canal's scarp, inclined with respect to the wall and accompanied by fragments of planking both above and below the alignment. An immediate inspection carried out by archaeologists from the University of Udine made it possible to recognise a regular alignment of frames, with planking boards featuring mortises and tenons, the typical construction system of Roman ships. From the earliest observations, it was clear that the exposed wood showed recent degradation, whereas the portions continuing inside the bank were intact and compact: a condition indicating that the hull had remained protected by the sediment for centuries, before a change in hydrodynamic dynamics began to erode its cover (**Fig. 2**). This recent shift in hydrodynamic behaviour is consistent with the climate-driven changes documented in the northern Adriatic, where rising sea levels, altered tidal amplitudes and increased storm frequency have intensified erosive processes along lagoon margins, effects clearly reflected in the local morphology of the canal.

This hydrodynamic energy has recently shifted toward an erosive regime consistent with the broader climate-driven "marinization" documented for the Marano–Grado lagoon system (Fontolan et al. 2023). Here, sea-level rise combined with local subsidence[2], reaching rates of up to 1 cm/year in specific coastal sectors (Carbognin, Tosi 2002; Fontana 2023), has produced a measurable

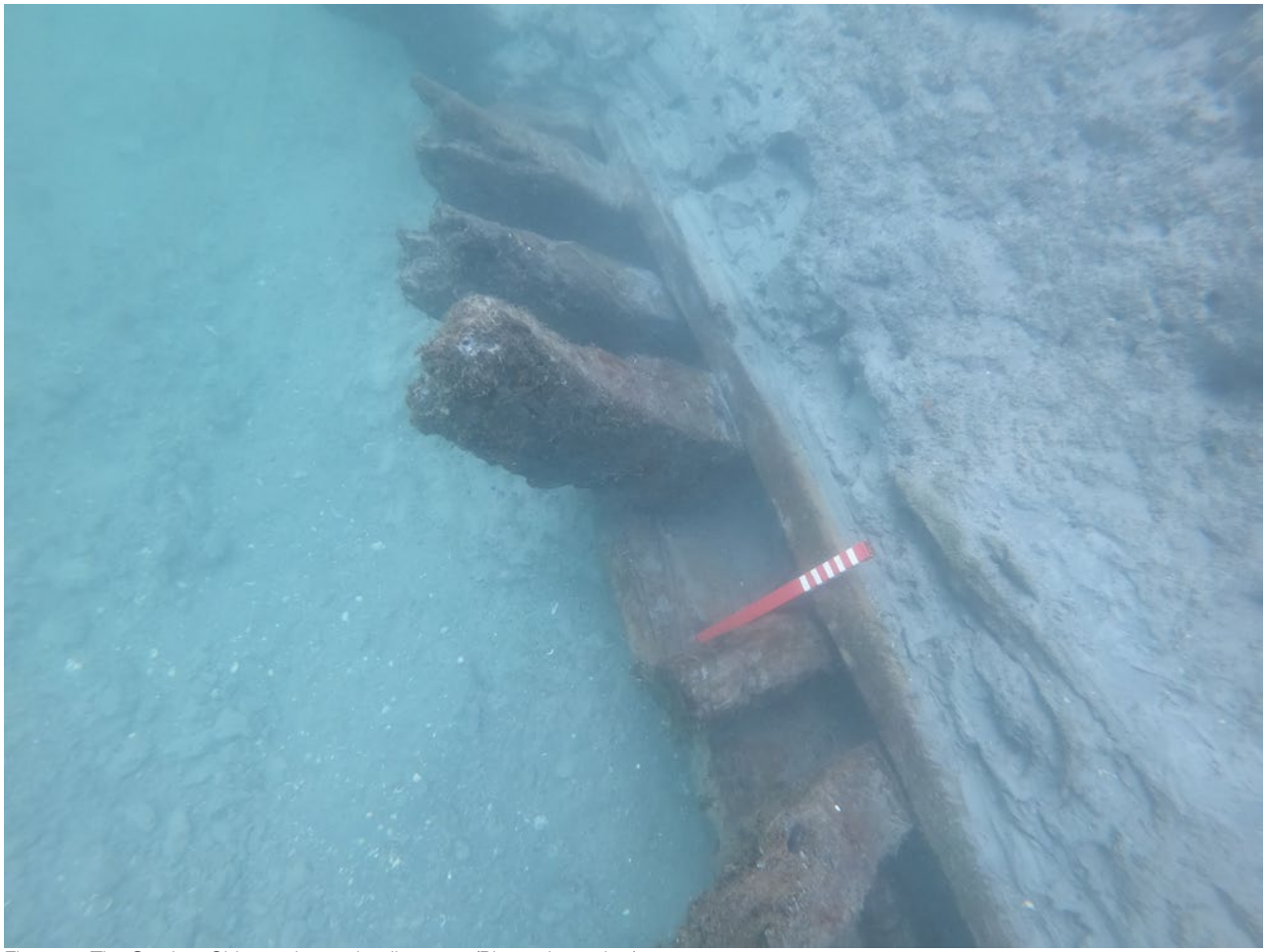


Figure 2- The Grado 6 Shipwreck after its discovery (Picture by author).

loss of intertidal environments, including a 16% reduction of salt-marsh surfaces between 1954 and 2006 (144 ha lost) and a 45.9% decrease in tidal-flat areas between 1964 and 2011 (2,672 ha lost) (Fontolan, Spadotto 2023).

In the specific area of Grado 6, the morphology of the canal, reconstructed through multibeam surveys by OGS, shows a bank that bulges outward corresponding to the hull, with an increasingly thin sedimentary cover towards the north-east. Following the discovery, the University of Udine initiated systematic monitoring of the site, producing periodic three-dimensional surveys using structure-from-motion techniques. Comparison of the 3D models obtained in subsequent years made it possible to measure with precision the progressive erosion of the bank (**Fig. 3**), documenting the advance of the detachment niche, the loss of sediment, and the exposure of structural timbers, including frames, planking, internal stringers, and a stempost, that had remained stably buried for centuries.
Despite the fragmentary nature of the visible parts, Grado 6 represents the first Roman shipwreck identified *in situ* in a lagoon environment, a rare depositional context of great informational value for reconstructing routes, port infrastructures, and geomorphological dynamics in the northern Adriatic during the imperial period (Capulli 2023b).

In view of the historical-archaeological significance of the site and the progressive exposure of the timbers, the Soprintendenza for Archaeology, Fine Arts and Landscape of Friuli Venezia Giulia has initiated a first phase of protection through the installation of tide-damping barriers and the covering of the timbers with geotextile fabric[3], while simultaneously launching studies for a permanent safety system.

The Case of the Lazise Shipwreck

The shipwreck known as the Galea of Lazise represents an exceptional case in the field of naval archaeology: one of the two warships deliberately scuttled in 1509 by order of the Venetian Senate

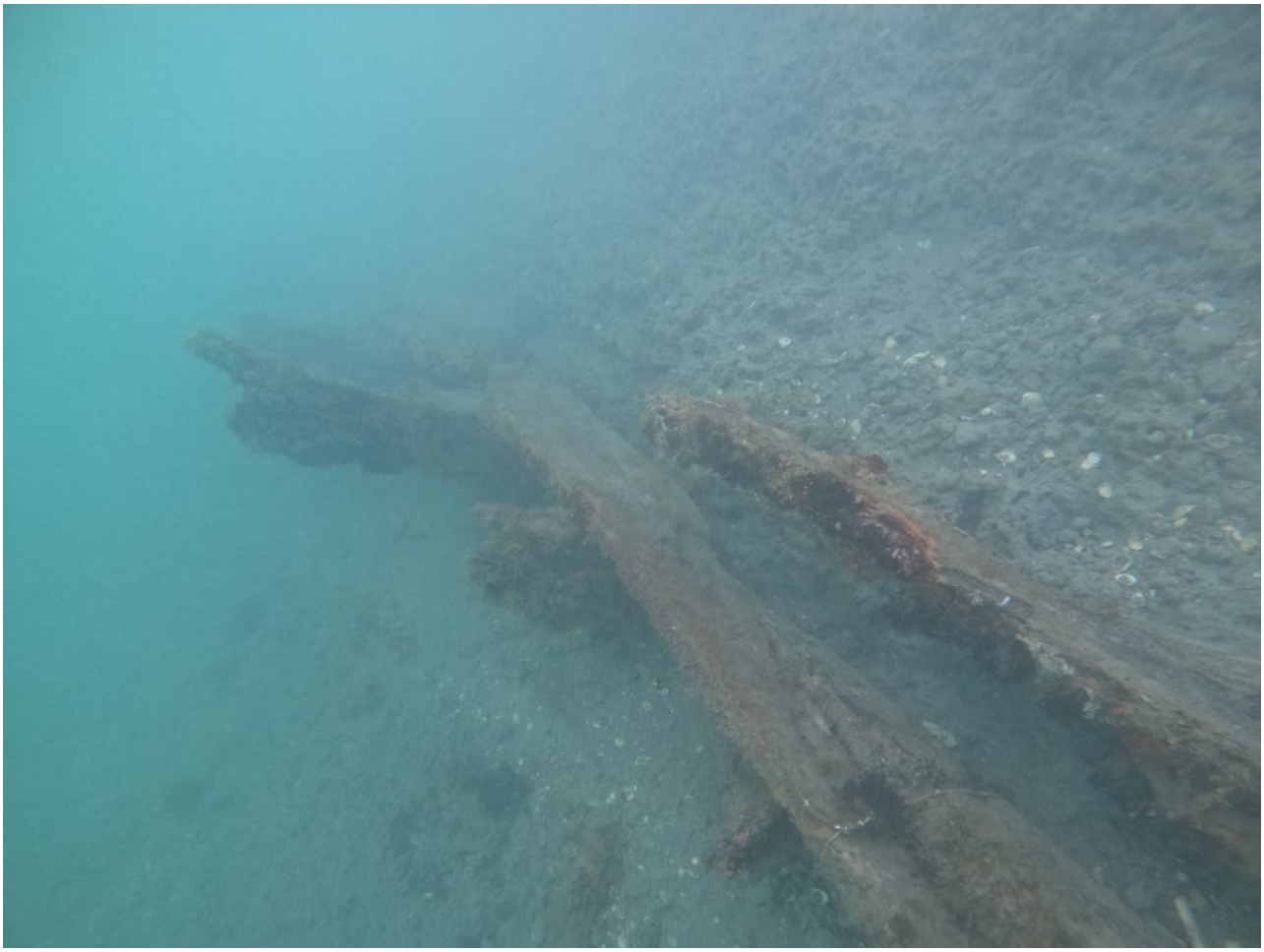


Figure 3- The Grado 6 Shipwreck after three years of erosion along the canal bank (Picture by author).

during the War of Cambrai and preserved in the fresh waters of Lake Garda. Its typological rarity, the preservation of the lower hull structure and the well-documented historical context have made it a fundamental reference for the study of Renaissance shipbuilding (Bondioli, Capulli 2010).

The wreck lies at a depth between 24 and 27 metres, on a muddy lakebed located roughly 500 metres south of the modern harbour of Lazise, within a deep lacustrine basin shaped by late Quaternary morphotectonic dynamics (Gasperini *et al*. 2020). Preserved for a length of just under 30 metres and a maximum width of three and a half metres, it rests in a doubly inclined position due to the natural slope of the bottom, with the bow at the southern, deeper end of the site and the stern to the north, at a shallower depth. The vessel settled on its starboard side, which, being more deeply covered by natural sediment, is also the portion that has been better preserved. Several structural elements of the original hull are clearly visible, including the keel, frames, keelson and mast step (Capulli 2003). The story of the scuttling has long remained alive in local memory, especially among fishermen who sensed the presence of the hull where their nets snagged on submerged timbers. Nevertheless, the official discovery of the wreck occurred only in the summer of 1962, and from that year onward several excavation and documentation campaigns were carried out, the last of which took place in 2003. Many years later, within a broader project of the University of Udine known as Benacus, an integrated research initiative combining historical and archival study, geophysical prospection and underwater inspection, a monitoring dive was conducted on the wreck in 2019 (Capulli 2023c). This provided the opportunity to observe that the exposed portions of the hull were heavily colonised by an almost uniform layer of invasive bivalve molluscs of the species Dreissena polymorpha.[4]
During the 2019 inspection, the removal of the mussels in a small test area (**Fig. 4**) made evident what had initially been only vaguely perceptible: the wood had become noticeably thinner, with nail heads now protruding several centimetres from the keelson. This condition appears consistent with the biological pressure exerted by dense colonies

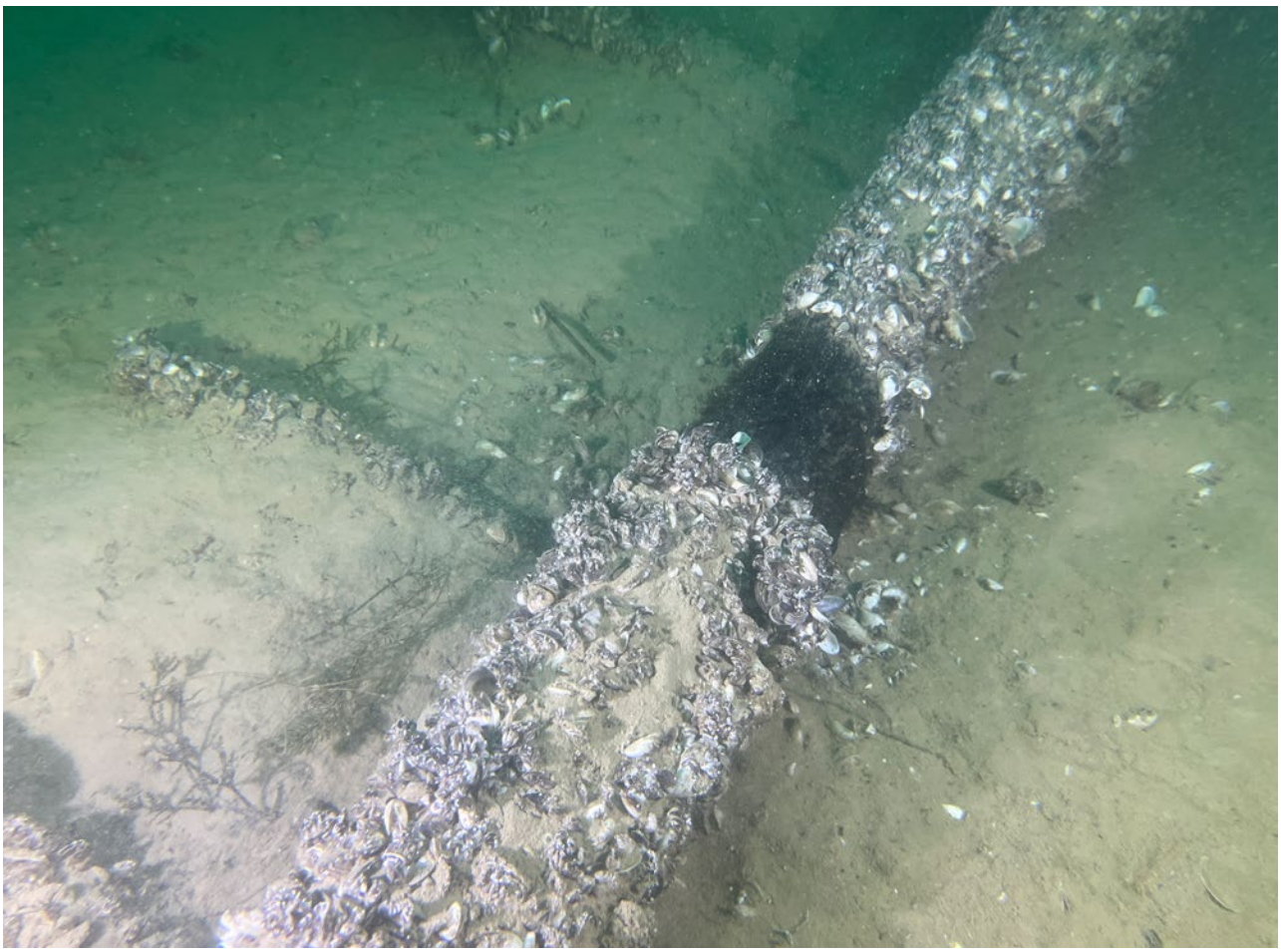


Figure 4- Lazise Shipwreck: detail of a section of the keelson after removal of the mollusks (Picture by author).

of invasive bivalves, whose prolonged settlement and metabolic activity may have contributed to the degradation of the exposed wooden surfaces.

It should be noted that the presence of Dreissena polymorpha in Lake Garda has been documented since the 1970s (Bianchi *et al*. 1974; Franchini 1978), as part of a broader history of non-indigenous bivalve introductions into the lake (Cappelletti, Ciutti 2017); the mollusc was therefore present in the basin for decades, including during the excavation campaigns of 1990, 1996, and 2003. However, its occurrence remained historically confined to shallow waters, as the species requires temperatures of at least 11 °C during its reproductive period to support larval development and colonization success (Orlova 2002).

Long-term limnological analyses show that Lake Garda is undergoing a measurable warming trend, with surface rates between 0.015 and 0.020 °C per year and record deep-water temperatures recorded in 2015–2016, driving an overall average temperature increase of +1.6 °C (Salmaso *et al*. 2018, 2020). This thermal shift has expanded the species' niche downward into deeper bathymetric zones, enabling its proliferation at the 24–27 m depth of the wreck.

In addition, climate-model simulations applied to several deep southern perialpine lakes (including Annecy, Ammersee, Geneva, Constance, Iseo and Maggiore), consistently project a future increase in water temperature and a reduction in winter mixing depth; since Lake Garda already exhibits comparable warming rates and has recently recorded unprecedented deep-water temperatures, these modelled trends provide a robust indication that similar thermal conditions are expected to intensify in the lake over the coming decades.

Taken together, these drivers act cumulatively: the initial human-mediated introduction of Dreissena polymorpha, the subsequent climate-driven warming that enabled its downward expansion, and the recent establishment of Dreissena bugensis. First documented in Lake Garda in 2022 (Salmaso *et al*. 2022), the quagga mussel is rapidly expanding across depth gradients (Ciutti *et al*. 2025), likely introduced via unintentional overland transport on recreational boats and fishing gear. Combined, these biological pressures accelerate the deterioration of the exposed timbers.
Given the progressive deterioration of the timbers of this unique wreck, the Superintendent of Archaeology, Fine Arts and Landscape of the provinces of Verona, Rovigo and Vicenza has initiated a first phase of protection, involving the removal of the invasive malacofauna and the covering of the exposed wooden structures with geotextile.5 The intervention also provided an opportunity to update the available documentation through new technologies, producing a three-dimensional model of the treated area.

Conclusions

The two shipwrecks discussed here remind us that underwater cultural heritage is not a static archive, but a living system that reacts to environmental change. In the lagoon, climate dynamics accelerate erosion and expose structures that had remained sealed in sediment for more than sixteen centuries. In the lake, rising temperatures reshape ecological balances and allow invasive species to colonise depths that were once inaccessible.

These processes are different, yet they share a common origin. Their contrast shows how climate change generates localised and divergent scenarios, altering the exposure and vulnerability of sites in ways that depend on their specific environmental settings. This diversity also highlights the need for shared protocols and best practices, capable of providing a common framework while remaining adaptable to contexts as different as Grado and Lazise. Each site therefore requires a tailored strategy, grounded in observation, documentation and adaptive management.

These contrasting site responses are consistent with well-documented regional trends, as northern Adriatic coastal systems are already experiencing accelerated sea-level rise and more frequent extreme sea-level events, with multidecadal analyses showing rapid morphological changes in nearshore sandbanks and lagoon environments and regional projections indicating that, even under the low-emission RCP2.6 scenario, mean sea level could rise by an additional 40 cm by 2100, substantially increasing the inundation risk for Grado during episodic storm-driven sea-level surges of 128 cm.

We may not have definitive solutions, but we do have a responsibility: to recognise these changes and to respond to them with the best tools available.

Notes

1- Holocene sedimentation alternates fine and coarse layers, reflecting climatic oscillations between warmer and colder phases.

2- “Eustatic change” refers to global sea-level variations driven by climatic and glacial processes, while “natural and anthropogenic subsidence” combines geological ground lowering with human-induced contributions.

3- The protection works were carried out by the company Archeotecnica under the scientific supervision of Giorgia Musina of the Soprintendenza and the field direction of the author.

4- The introduction of Dreissena polymorpha into Lake Garda is linked to boat transfers between water bodies without adequate hull-cleaning procedures.

5- The protection works were carried out by the company Idra under the scientific supervision of Alessandro Asta of the Soprintendenza and the field direction of the author.

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hic sunt futura

The University of Udine (Italy) combines a unique civic origin after the 1976 Friuli earthquake with a strategic crossborder position between the Latin cultural area and the neighbouring Germanic and Slavic regions. It is a dynamic institution committed to research, education and heritage preservation, with longstanding experience in cultural and underwater archaeology.



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Operationalizing a Novel Climate Change Risk Assessment Framework on Norwegian Coastal Stone Age: The Vingen Rock Art Case Study

Julius John Dimabayao, Laro González Canoura, and *Javier L. Lara*

Introduction

Stone Age rock art represents an important form of artistic expression and communication by ancient human societies. Created through engraving, pecking, carving, and/or use of natural pigments on hard stone surfaces, these sites are generally exposed to environmental processes. Such processes are not necessarily new and have existed naturally as site formation processes that affect archaeological materials (Schiffer, 1987). However, anthropogenic climate change alters these processes by changing their frequency, intensity, and duration (IPCC, 2021). Therefore, categorizing a site as simply being threatened by climate change provides limited information for heritage management. It becomes apparent that climate risk assessment should distinguish these dynamics: which processes pose threats and become Hazards (H), which archaeological elements are exposed (exposure, E), and how their intrinsic properties make them vulnerable (vulnerability, V).

The Vingen rock carvings in Vestland County, Norway, are used as a case study for a site-level detailed IPCC-aligned climate risk assessment (**Fig. 1**). Although situated in a coastal fjord environment in western Norway, Vingen is not primarily threatened by sea-level rise, wave action, or coastal erosion, as ongoing post-glacial land uplift partly offsets rising sea levels along the Norwegian coast (Richter *et al*., 2012). This particular case study illustrates why climate risks facing coastal heritage are not only limited to typical coastal hazards, since rock art preservation is also influenced by terrestrial and atmospheric processes that closely interact with coastal processes. Vingen therefore provides an example of how climate change risks affecting coastal heritage can extend well beyond direct interaction with the sea.

This approach combines H, E, V as components that make up the risk (IPCC, 2022). The exposed rock surfaces at Vingen are subject to multiple interacting environmental processes, while existing archaeological documentation provides a basis for examining differences in exposure and vulnerability within the site. This risk assessment details how projected changes in selected climate-related hazards interact with the exposure and vulnerability of three documented rock-art panels. In doing so, this framework also evaluates the applicability, data requirements, and limitations of the methodology, which provides a basis for subsequent refinement through field observations and more detailed site data.

Site Assessment and Approach

Vingen is a major rock-art landscape in northern Europe, with more than 2000 recorded rock art carvings (Lødøen and Mandt, 2010). Because of its archaeological importance, environmental context, and preservation conditions, Vingen provides a suitable case study for demonstrating how climate risk assessment can be operationalized due to its extensive available archaeological knowledge in the literature and online. The site contains numerous exposed rock motifs that are continuously affected by water, moisture, lichen and plant growth, weathering, and seasonal temperature variations (Bjelland *et al*., 2010a, pp. 43–54; Bjelland *et al*., 2010b, pp. 63–65, 71–75, 90–103). The existing



Figure 1- Vingen rock art, showing some motifs from the panel in the Hardbakken ridge. Reproduced with permission from The University Museum of Bergen.

documentation of these processes and the physical conditions of the rock panels provides an important basis for distinguishing which processes are potentially modified by climate change.

The assessment focused on three well-documented rock art panels that can be accessed online: Hardbakken, Brattebakken, and Vehammaren (Virtuelle Vingen, 2018). These panels are closely situated to each other, hence, experience broadly similar local climatic conditions. However, they were treated as individual objects/units of assessment (OUAs), which allowed differences in their local setting and physical characteristics to be considered. This distinction is central to the site-scale assessment, where it is assumed that a projected change in a climate-related hazard does not necessarily translate into the same level of risk across different parts of the archaeological site.

Six climate-related hazards most relevant to the preservation of the rock surfaces were identified based on supporting documentation in the literature: increased runoff, moisture persistence, biological colonization (particularly lichen growth), chemical weathering, surface erosion, and freeze-thaw cycles. Their projected changes were characterized using climate indicators representing the environmental processes associated with each hazard, which were derived from datasets published by the Norwegian Climate Service Center (Norsk klimaservicesenter, n.d.; Dobler *et al*., 2025). Conditions from the climate indicators for years 1991-2020 reference period were compared with projections for mid-century (2041-2070) and end-century (2071-2100) under three climate scenarios (RCP2.6, RCP4.5, and SSP3-7.0). These were used to determine how strong is the increase or reduction of the change in the hazards that affect the preservation of the rock panels.

Risk was subsequently assessed through the interaction of H, E, and V. Exposure represented the degree to which each rock-art panel is spatially related to a given environmental process, while vulnerability represented characteristics that influence its susceptibility to damage, including its physical state, informational context, intrinsic sensitivity, and intrinsic capacity. These components were rated using a standardized scoring matrix, and were combined to derive a relative risk index for each hazard and OUA. Confidence was assessed separately to indicate the strength of the available evidence supporting the resulting risk estimates.

Results

Risk index (Ri) calculations show that climate change does not modify all environmental processes affecting the Vingen rock art in the same direction or magnitude. The dominant changes identified are not directly related with the conventional coastal hazards, but are associated with processes acting on the exposed rock surfaces. Across the scenarios and time horizons assessed, increased runoff, biological colonization, chemical weathering, generally show increased risk levels, while changes in moisture persistence and surface erosion remain comparatively small. In contrast, freeze-thaw activity decreases, with stronger risk reductions toward the end of the century (see **Fig. 2**). These imply that climate change does not uniformly intensify all existing deterioration processes, but instead changes their relative importance through time.

The changing hazards also translate into different levels of risk among the rock panels analyzed because of slight differences in local exposure and vulnerability. Biological colonization and chemical weathering emerge with the largest increases in risk, although their relative importance differs among panels. Biological colonization produces the greatest increase at Vehammaren (Ri = +31.25), reflecting its combination of high exposure and vulnerability, while chemical weathering is highest at Hardbakken (+31.63), where exposure to this process is comparatively high.

Increased runoff shows smaller but consistent increases, particularly at Hardbakken (+20.13), whereas moisture persistence produces only modest changes across the three panels. Surface erosion shows the smallest positive risk changes (+6.25 to +8.63), despite its projected increase as a climate-related hazard. These results illustrate how the magnitude of hazard change alone does not determine archaeological risk because the local exposure and vulnerability conditions of each panel modify the resulting risk.

The clearest contrasting pattern is freeze-thaw cycles, for which due to projected increase in ambient temperature and decrease in frost days

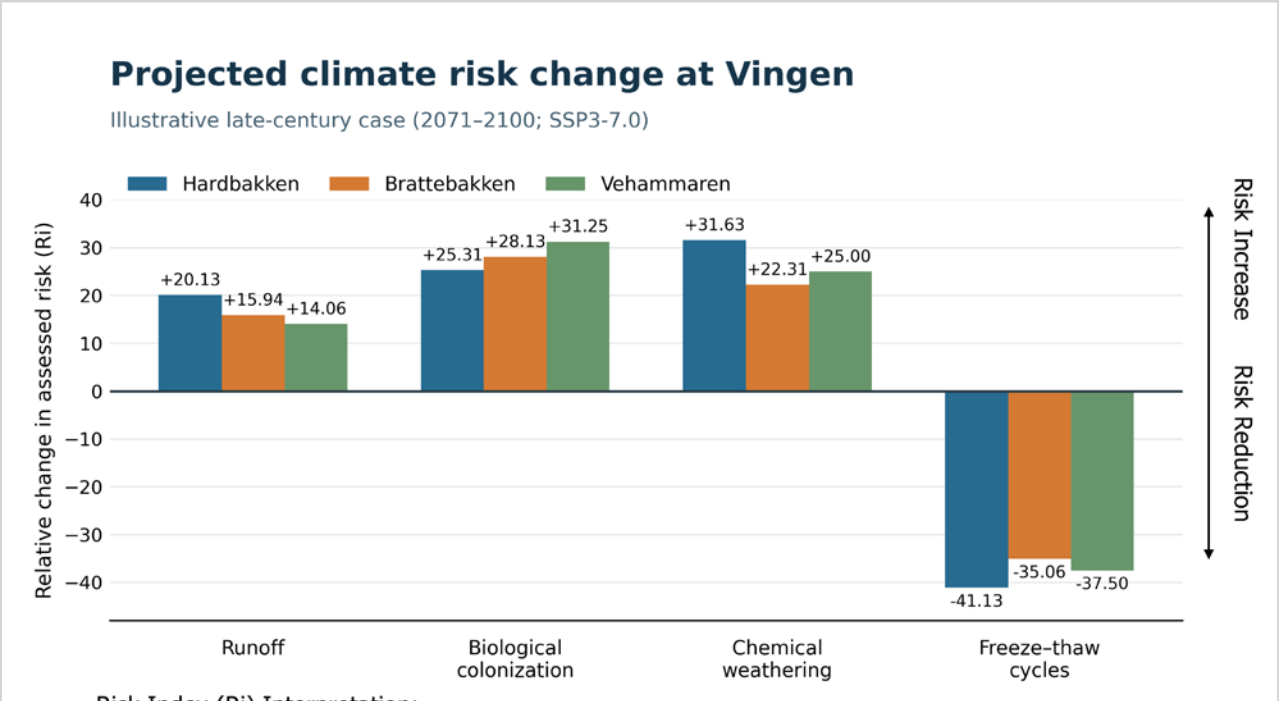


Figure 2- Illustrative end-century changes in assessed climate-related risk for three rock-art panels at Vingen under the higher-warming SSP3-7.0 climate scenario. Positive Risk Index (Ri) values indicate risk increase relative to the baseline 1991–2020 reference period; negative values indicate a risk reduction. Values are relative index scores, not percentages or predicted amounts of damage. The full assessment also considered two other scenarios, an earlier future period, and two additional processes.

(Dobler *et al*., 2025), the risk level decreases across all panels, reaching –41.13 at Hardbakken. This does not imply that freeze-thaw ceases to affect the rock art, but that its climate-related contribution to risk is projected to decrease relative to the historical baseline as freeze-thaw conditions become less frequent.

Conclusions

Climate risk assessment at Vingen demonstrates how climate change affects rock art conservation, particularly with regards to which hazards may change and how they would interact with the rock panels. Assessing the three rock panels as separate units revealed differences that are crucially important for close observation. Additionally, this work also shows why a projected change in a climate-related hazard should not on its own be interpreted as damage to archaeological material.
The assessment nevertheless reflects the evidence currently available. Published conservation studies and digital documentation provide substantial information about Vingen, but these cannot fully represent the present condition of every carved surface. Confidence ratings therefore distinguish better-supported assessments from those requiring further field observation. Therefore, the results should be understood as a basis for identifying priorities for management decision.

This work at this stage intends to establish a systematic way to connect climate-related hazards with the specific conditions of archaeological receptors. Findings can guide more detailed site and panel risk assessments, with added field surveys of surface condition, water pathways and biological cover. At a higher resolution, interdisciplinary inputs from archaeologists, conservators, climate scientists and engineers could help establish how particular environmental changes translate into material deterioration. Where appropriate evidence exists, closely observing material damage could strengthen this link by relating the intensity or duration of a process to its likely physical effects.
Lastly, this work allows future assessments to move beyond the relative risk ratings to a more robust evaluation of potential impacts that led to recommendation of feasible adaptation measures. The present results provide a preliminary basis for heritage managers of Vingen, or managers of other parietal art, and potentially other heritage sites as well, on how to make conservation decisions based on a systematic and evidence-based approach, and on how next to proceed as site evidence improves.

IHCantabria is a joint research institute of the Universidad de Cantabria and the Government of Cantabria (Spain), specialising in environmental hydraulics. Its multidisciplinary research integrates field observations, laboratory experimentation and numerical modelling to address challenges including climate change, coastal risks, marine and coastal engineering, environmental management and adaptation. With more than 200 experts and extensive participation in national and international R&D projects, IHCantabria increasingly applies its expertise in climate science, risk assessment and coastal processes to cultural heritage, developing interdisciplinary approaches to understand climate-related threats and support the adaptation, management and preservation of coastal and archaeological heritage.



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SUBNORDICA: the challenges of ethical, net zero development of the world's coastal shelves

Katrine Juul Andresen, Peter Moe Astrup, Vincent Gaffney, and Svea Mahlstedt

Following the last glacial maximum, c. 20,000 years ago, global sea-level was c.130 metres lower than the present and c.20 million km2 of new territory was exposed around the world's continental margins (**Fig. 1**). In Europe alone, the continent increased in area by as much as 40%, exposing more than 3 million km2 of new land. Yet, progressive global warming and sea-level rise transformed and inundated these landscapes, and by c. 6,000 BCE, these unique landscapes had almost totally disappeared as the world morphed into the shape we are familiar with today (Gaffney 2010; 2022). These vast territories with their coastal plains, low hills, lakes, river valleys, marshes, estuaries, shorelines and offshore islands, provided some of the most attractive areas for past human settlement. They were also linked to those critical periods when humanity spread across the world. The peopling of the Americas, for instance, is linked to migration across the area of the Bering Straits, via a lost land often referred to as Beringia (Hoffeker *et al*. 2023). Largely unexplored, the lands lost to the sea are known to preserve unique environmental and palaeoclimatic archives. The archaeological evidence that must lie hidden beneath the sea has the potential to transform our understanding of societal response to periods of dramatic climate change in prehistory. The challenge to explore these lands is formidable, buried deep beneath the sea and marine sediment they have been difficult

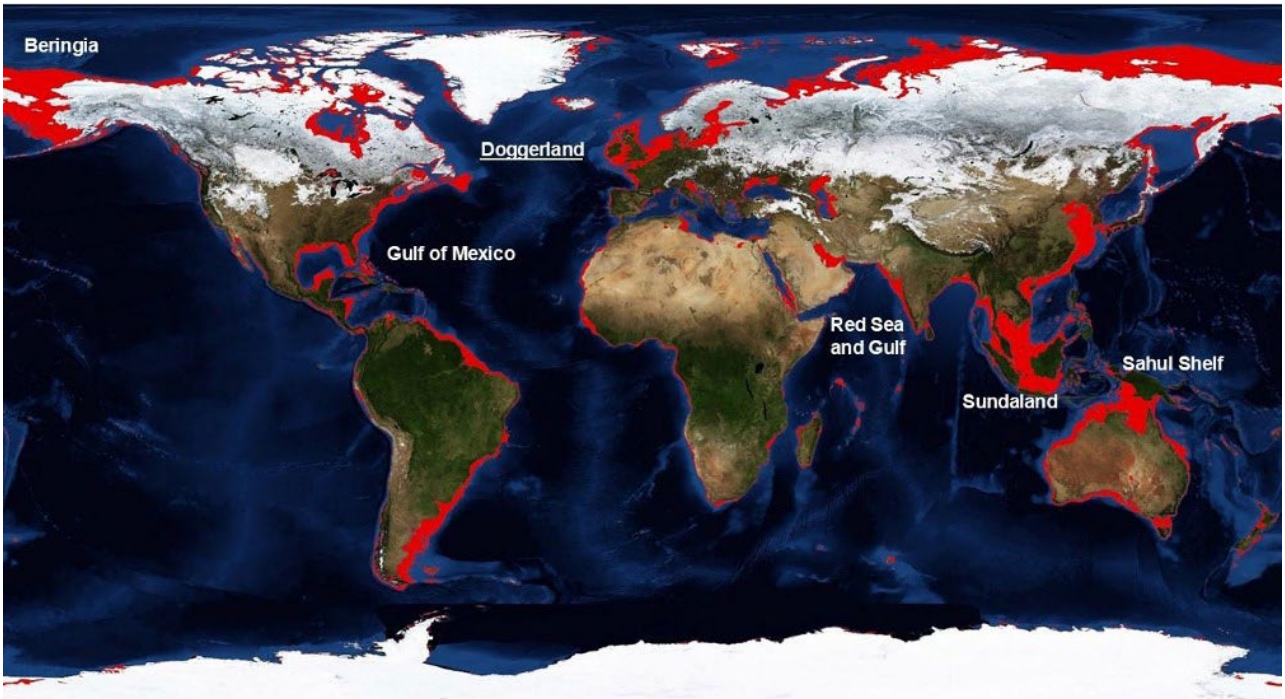


Figure 1- The world at the end of the last Ice Age. Inundated land is shown in red (Submerged Landscapes Research Centre, University of Bradford).

to explore or even access. The consequence of this situation is that this important aspect of our shared, global heritage has largely been forgotten by archaeologists and the global public.

Until very recently, it had been convenient to believe that much of the evidence now covered by seas and oceans was not simply lost but probably destroyed by the action of waves and rising sea levels. However, there is increasing evidence that this is not true. The discovery and excavation of archaeological sites in shallow coastal waters has demonstrated the remarkable preservation of prehistoric materials including wood and textiles (Jørgensen 2013). More recently, dramatic discoveries off the Germany and French coast have recorded evidence for massive stone structures. Some are more than 10,000 years old and must be linked to prehistoric hunting (Geersen *et al*. 2024). Ironically, such finds are largely absent on dry land, where agriculture and urban development have dramatically changed the landscape and almost entirely removed such evidence. Advances in technology have also begun to reveal these lost lands. The evidence now being recovered through remote sensing data, often collected by the offshore sector and from research vessels, is now revealing lost rivers, coastlines, marshes and lakes. Today we can map and date entire prehistoric landscapes that were last seen more than 7,000 years ago.

Despite such innovation, our understanding of the people and their lifestyles is revealed only in tantalising glimpses. Especially in tidal waters, archaeological finds are rare and usually the product of chance discovery. Artefacts are often found in the nets of trawlers, recovered by sports divers, beachcombers, fishermen or by offshore industrial activity including dredging for aggregates. The Baltic Sea yields a higher number of sites, as the shelter from open-ocean conditions allowed for slightly different regional developments and has made sites much easier to locate and explore (Bailey *et al*. 2020).

But there, as in other areas, searches for earlier material at greater depth are hampered by technical difficulties. These challenges include working in hostile environments, and variable conditions of preservation and visibility resulting from the locally unpredictable erosion or burial under marine sediments. Chance finds only rarely

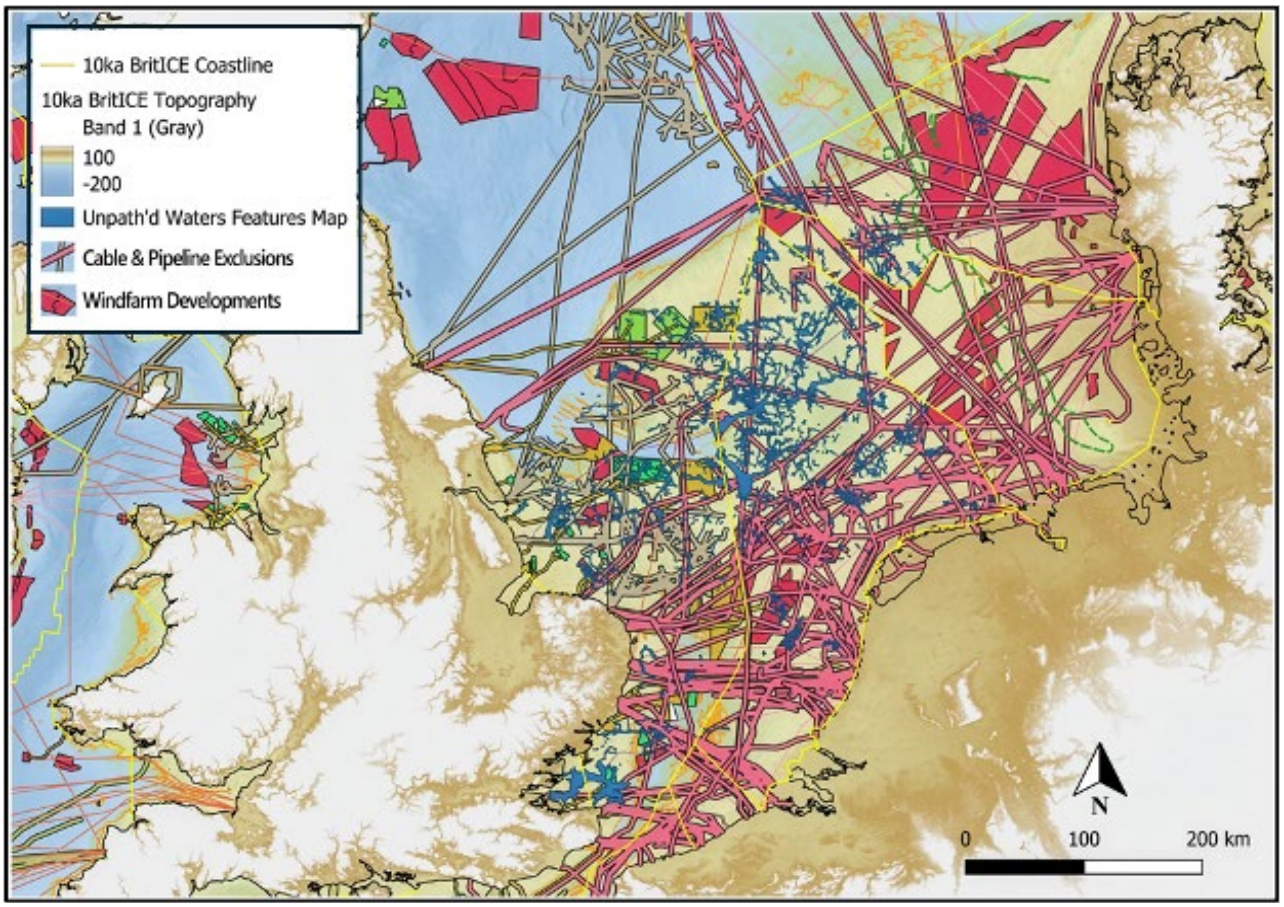


Figure 2- Density of infrastructure development in the southern North Sea in relation to Doggerland coastlines (Figure provided by Dr Andrew Fraser, Submerged Landscapes Research Centre).

have any archaeological context. Unless we can develop new ways of exploring such landscapes, we will never be able to understand the long, and complicated, relationship between humans, climate and consequential massive landscape changes.
The climate is changing again, impacting these lost and unexplored landscapes. The necessity to meet net-zero goals has resulted in the extensive development of the continental shelves for energy generation. Often linked to the construction of wind farms, the scale of offshore construction today is without parallel: many of the areas destined for future development align almost completely with the landscapes lost to the sea (**Fig. 2**). These changes now threaten to degrade our ability to prospect for evidence for past human adaptation in the face of dramatic climate change. The density of development across Doggerland is illustrated in figure 2. It should be stressed that the impact across Doggerland and similar palaeolandscapes, is not simply the threat of destruction resulting from the construction of wind farms. The webs of cabling and infrastructure that support windfarms may also render large areas of the seabed inaccessible to future investigation (Walker *et al*. 2024). Society may soon lose the chance to explore these unique landscapes, or even the opportunity to formulate policy on the management of such underwater cultural heritage. The density of development across the area of the southern North Sea, illustrated in (figure 2), demonstrates that the almost the entire area of Doggerland is now under threat.

We need to act urgently, and the European Research Council has funded a large-scale Synergy project in anticipation of the emerging crisis - *Subnordica* (https://projects.au.dk/subnordica/about). The pan-European team is confronting the technical challenges of exploring inundated landscapes at scale (**Fig. 3**). Working across the North Sea and the Baltic Sea, the project aims to develop new methods for recreating the submerged landscapes and rediscover evidence of human settlement now lost beneath metres of water and marine sediments.

Led by the Universities of Aarhus and Bradford, the Moesgaard Museum and the Lower Saxony Institute for Historical Coastal Research, *Subnordica* will tackle these challenges through a structured and systematic programme of research.

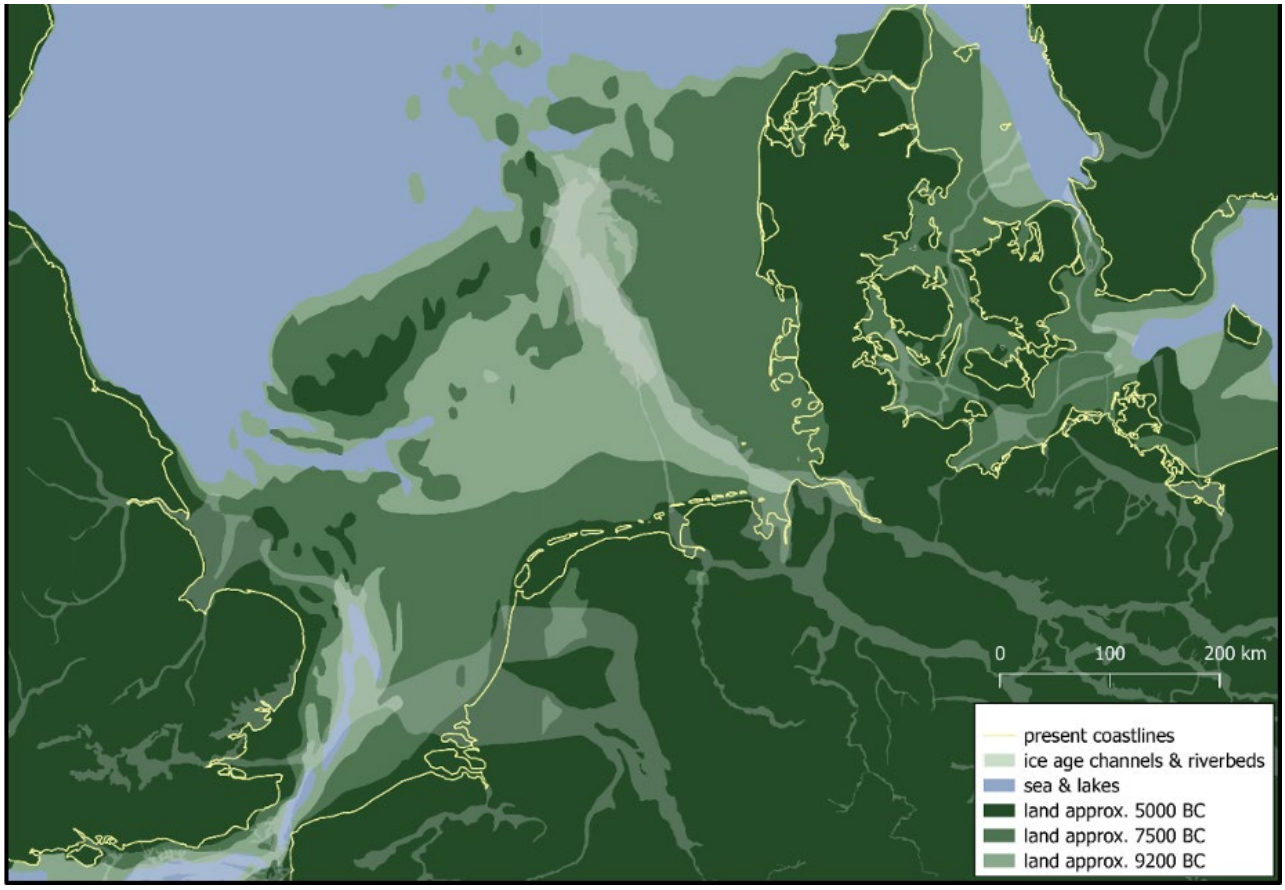


Figure 3- The Southern North Sea and Baltic study areas (Image by Svea Mahlstedt based on the European Prehistoric Atlas (https://zbsa.eu/en/european-prehistoric-and-historic-atlas/).

It brings together four uniquely qualified teams, each with complementary skills and experience in a synergistic project that integrates the natural sciences. This includes geophysics, remote sensing, marine geology, palaeoclimatology, geochemistry, molecular biology; the humanities – archaeology, environmental archaeology, cultural heritage management; and the digital sciences. Today, we are generating landscape level simulations of prehistoric settlement at a supranational scale, based on the geophysical, geomorphological, sedimentological and archaeological characteristics of known sites from Denmark, Germany and the Netherlands (**Fig. 4**). Artificial Intelligence is also being applied to integrate data from existing and newly acquired geophysical and geomorphological datasets, to refine our models of these lost landscapes and identify potential targets for exploration.

Following this essential work, *Subnordica* researchers are now mounting large research ship missions in the deeper waters of the North Sea, as well as diver survey and excavation in the shallower waters of the Baltic to validate the results of computer modelling (**Figs. 5** and **6**). Such work will also provide sediment samples to recreate the changing climate and environment and recover archaeological evidence to reveal the lost lifestyles of our ancestors (**Fig. 7**).

The development of reliable methodologies for prospection of marine palaeolandscapes, in conjunction with the offshore sector, will allow

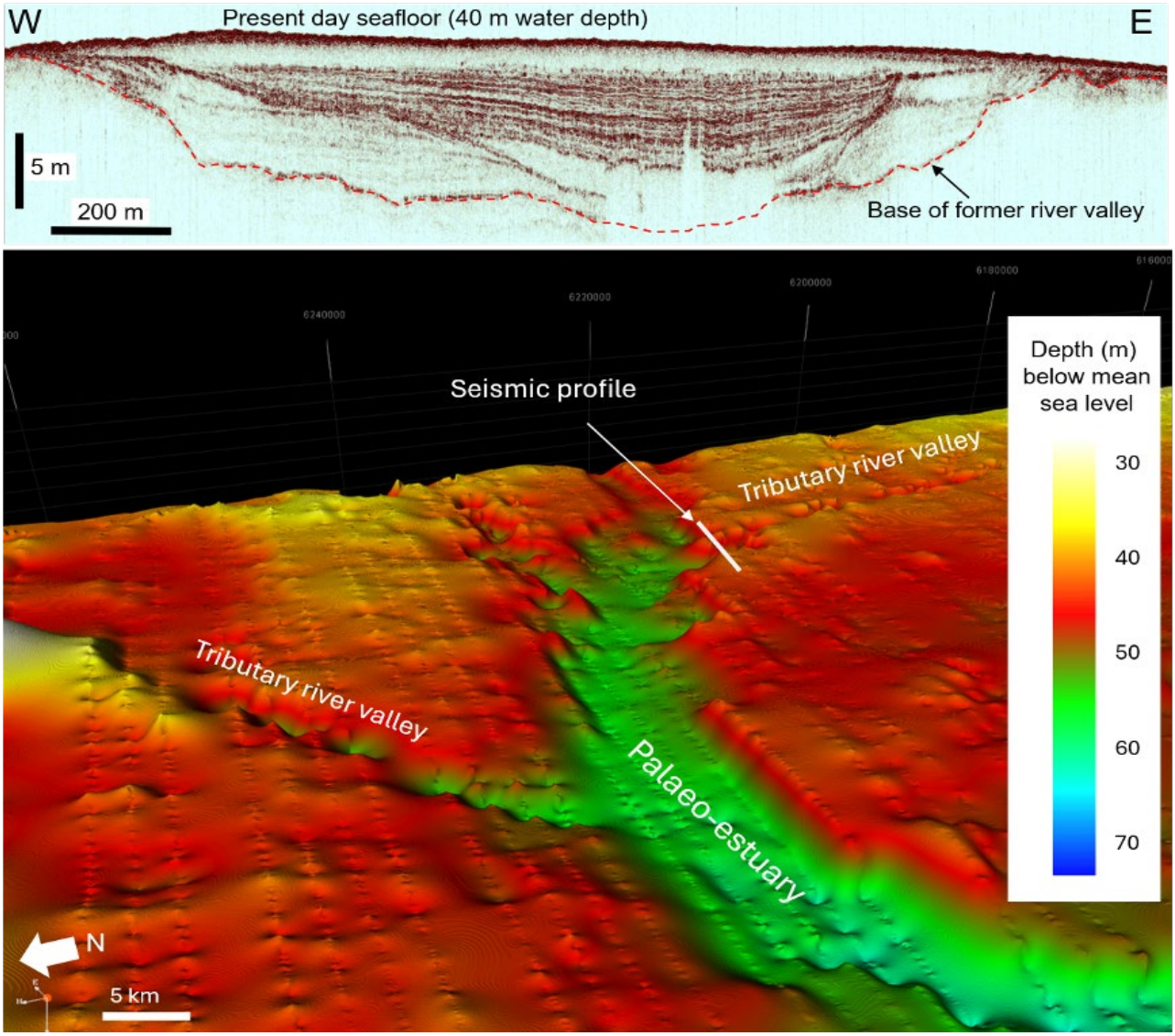


Figure 4- Palaeolandscape surface (bottom) mapped in the North Sea from geophysical data showing an estuary with tributary river valleys. The seismic profile (top) shows how the palaeolandscape is found below the present-day seafloor and a thin layer of marine sand (Image by Katrine Juul Andresen).

archaeologists around the world not only to explore these landscapes wherever they exist, but also to raise shared concerns for their preservation in the face of the unintended consequences of climate action. If this is not attempted, large areas of humanity's most important archaeological landscapes will remain unexplored. We will also lose an important opportunity for archaeology to contribute to our understanding of past climate change, whilst also contributing to the preservation of heritage through the ethical net-zero development of the coastal shelves, based on the work of the project.

For further information on *SUBNORDICA* visit www.subnordica.eu



Figure 5- Recreational diver testing a novel underwater GPS setup while searching for new submerged sites in Aarhus bay (Photo. Peter Lajgaard).

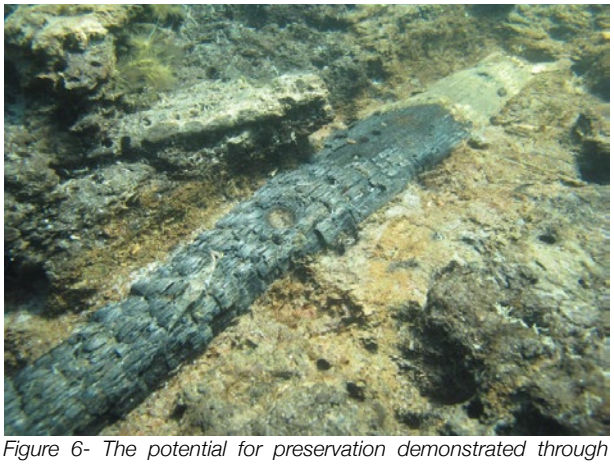


Figure 6- The potential for preservation demonstrated through the presence of burned wood in peat layers. Associated with a Kongemose site located in 2025 in Aarhus bay (Photo Peter Moe Astrup).

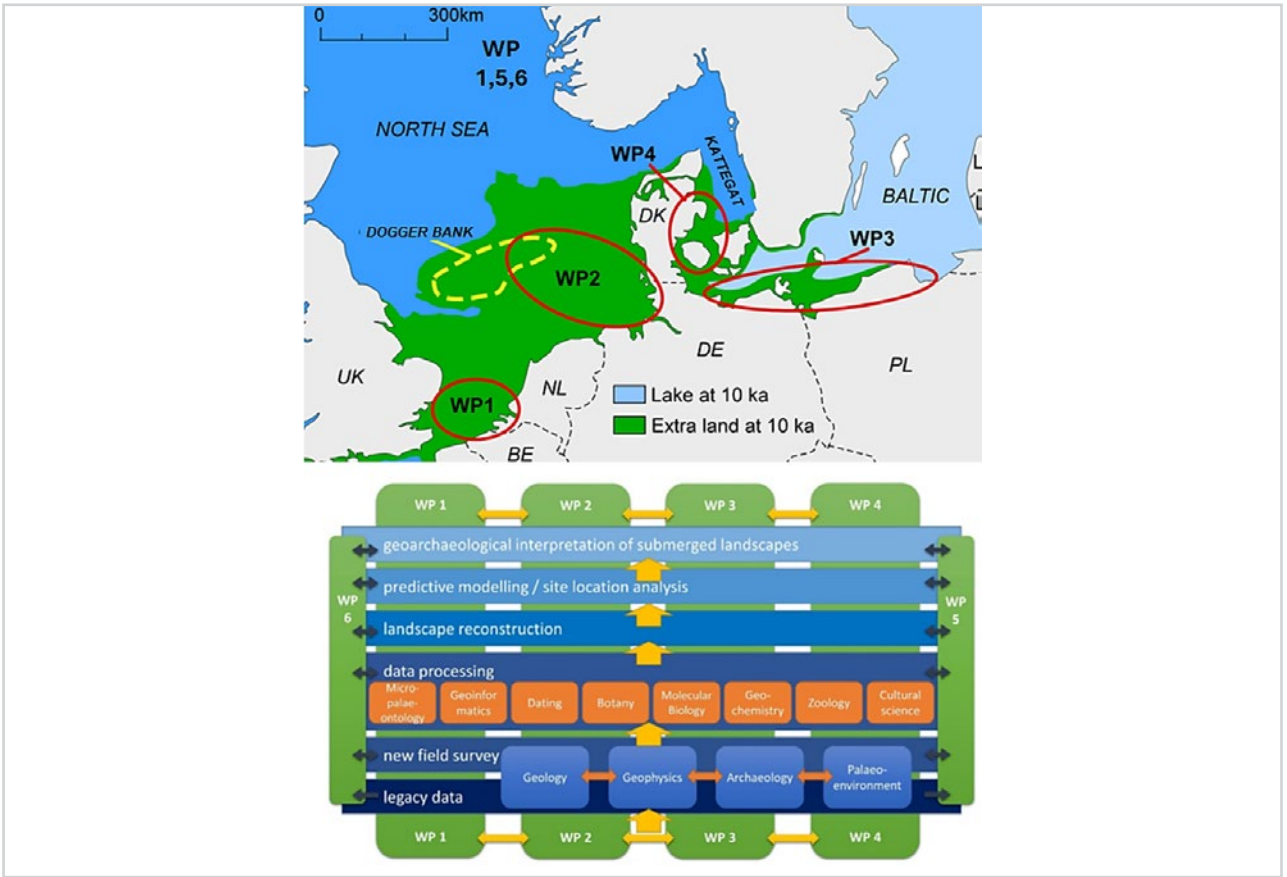
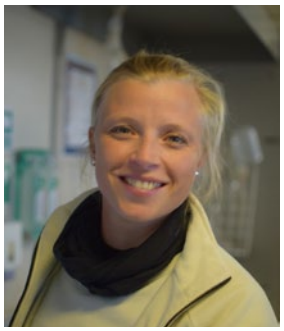


Figure 7- SUBNORDICA*: the project structure and location of primary work packages. Work Packages 5 and 6 relate to cross project modelling and data management (*SUBNORDICA *team).*

The landscapes that extended for millions of square kilometres offshore of the world's coastlines due to low sea-level during the last glaciation and were then drowned by sea-level rise, but are known to preserve valuable archives of landscapes, palaeoclimatic change and stratified archaeological remains, with the potential to transform understanding of human history in this period of dramatic change. The absence of archaeological sites across much of this vast area prevents realisation of this potential. SUBNORDICA *will address these issues by combining survey data from four regions in the North Sea and Baltic Sea, and using artificial intelligence to develop machine-learning routines to identify new targets of archaeological potential for more detailed investigation.*

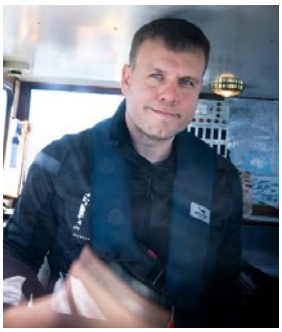
SUBNORDICA *is funded by the European Research Council as a 6-year Synergy Grant project (101119164).*



Professor Katrine Juul Andresen

Professor in Marine Geophysics, Katrine Juul Andresen, is co-leader of the SeisLab Aarhus research group at the Department of Geoscience at Aarhus University, and chair of the newly established Danish Marine Geophysical Research Infrastructure (DanMARGIN). Her research interests cover Quaternary geological processes including the evolution and preservation of submerged paleolandscapes. She is PI on the ERC-funded Synergy project SUBNORDICA *and the Carlsberg Foundation RisingSea project. Previous research projects include studies of ice dynamics at the Greenlandic Shelf, subsurface fluid migration, and munition at sea.*

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Professor Vincent Gaffney

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Dr. Svea Mahlstedt

Dr. Svea Mahlstedt specializes in the study of Stone Age settlement sites, both underwater and on land. She studied prehistory in Tübingen, Aarhus and Kiel, where she received her scientific divers' license and her PhD. Since 2014, she has been researching post-glacial hunter-gatherer cultures in Northern Europe through various projects at the Lower Saxony Institute for Historical Coastal Research (NIhK). She is PI for the southern Baltic Sea in ERC SyG SUBNORDICA *and the project Mesolithic in Northwestern Germany funded by German Research Foundation.*

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Coastal Erosion and Its Impact on Archaeological Heritage: Case Study of Tipaza (Algeria)

Rafik khellaf

Introduction

Algeria's 1,600 km coastline holds an exceptional archaeological heritage, testifying to millennia of human occupation and Mediterranean exchanges. Today, these coastal remains face unprecedented environmental threats driven by marine erosion, wave action, and climate-induced sea-level rise. Focusing on Tipasa and its surrounding region, this study examines the mechanisms of marine degradation impacting littoral and submerged sites in order to support sustainable preservation and integrated coastal management strategies.

Overview of the Algerian Coastal Setting and Historical Context

Extending over 1,600 km in the Western Mediterranean, the Algerian coastline forms a strategic maritime facade connecting North Africa to Southern Europe and the Near East (Bouhafs, 2026). Shaped by the Tell Atlas, its contrasted relief of steep cliffs, bays, and wadi mouths—composed of sandstone, limestone, marl, and Upper Pleistocene deposits—is heavily exposed to marine erosion and weathering (Boughedir, 2015). Continuously occupied from Prehistory through Antiquity to modern times, these natural shelters supported successive maritime trade networks, from Phoenician and Carthaginian outposts to Roman and Ottoman port systems (Salama, 2006).

Coastal Archaeological Heritage of Tipaza: Distribution and Research Context

Recent university-led investigations combining pedestrian coastal surveys -Tipasa project- with remote sensing and mapping -MarEA project- (Quevedo *et al*., 2023) have renewed coastal historiography by unveiling a series of previously unrecognized shoreline and underwater installations (Khellaf *et al*., 2022). Nevertheless, the majority of these coastal deposits face acute vulnerability and imminent threats of degradation from marine erosion, storm surges, and anthropogenic pressure (Aoudia Benali & Chennaoui, 2017). (**Fig. 1**).

Archaeological sites in the Tipaza region facing coastal erosion: case studies

Coastal erosion severely impacts Tipaza's heritage, particularly at Tipasa and Kouali. At Tipasa, wave action along the 300 m Lighthouse cliff has carved basal notches and cavities (LEM, 2009), triggering block collapses and joint UNESCO-ICOMOS missions to recommend urgent protection (Beschaouch & Braun, 2006). This initiated geotechnical works, including concrete injections and rock armor placement (LEM, 2009). Identical dynamics affect the East Park, threatening necropolises, basilicas, and city walls (Aoudia Benali & Chennaoui, 2017). At Kouali, swells and runoff erode prehistoric deposits, Roman thermal



Figure 1- Roman quarry on the eastern coast of the Tipasa site "villa maritima" at the CET tourist complex © Rafik Khellaf.



Figure 2- Example of collapses in the western park of the Tipasa archaeological site.



Figure. 3- Example of the collapse of rocky headlands east of Tipasa (near Kouali) © Rafik Khellaf.

structures, and lime kilns on friable calcarenite headlands (Khellaf *et al*., 2022).

Coastal erosion severely impacts Tipaza's heritage, with acute vulnerability concentrated at Tipasa and Kouali due to accelerating climate-driven hazards. (**Figs. 2** and **3**). At Tipasa, hydrodynamic wave action and extreme storm surges along the 300 m Lighthouse cliff (10–15 m high) have hollowed out basal notches and underwater dissolution cavities in calcarenite sandstone overlying marly substrate (LEM, 2009). This ongoing undermining, triggers recurring block collapses, precipitating ancient sarcophagi, city walls, the Cardo Maximus, and Villa of the Frescoes into the sea, which prompted joint UNESCO-ICOMOS missions to recommend urgent protection and buffer zone extensions (Beschaouch & Braun, 2006). In response, geotechnical works were initiated, including concrete injections and rock armor placement at the cliff toe (LEM, 2009). Identical marine dynamics undermine the East Park (Sainte-Salsa), threatening eastern necropolises and ancient basilicas (Aoudia Benali & Chennaoui, 2017). At Kouali (Aïn Tagouraït), swells, haloclasty, and runoff erode prehistoric layers, Roman thermal structures, and lime kilns on friable headlands (Khellaf.R, Bensaidani.Y, 2023).

Climate change directly exacerbates these erosive processes through sea-level rise (SLR) and increased storm frequency (Reimann *et al*., 2018). Continental-scale IPCC assessments indicate that Tipasa's exposed area will increase from 2.6% at baseline (2010) to 6.7% under RCP 4.5 and 9.5% under RCP 8.5 by 2100, while return periods for extreme 100-year events shorten to 10-year events (Vousdoukas *et al*., 2022; Clarke, 2026) Locally, Coastal Vulnerability Index (CVI) assessments and spatial modeling performed via Google Earth Engine (GEE) and LisCoast under IPCC scenarios (RCP 4.5 & RCP 8.5) project a mean regional shoreline retreat of 24 m by 2100, reaching up to 488 m in friable sandstone sectors (Bouhafs, 2026). Inundated area under SLR rises from 1.93 km² in 2050 to 3.00 km² in 2100 (+55.4%), reaching 3.67 km² during RCP 8.5 extreme sea-level (ESL) events, where 2050 extreme storms generate flood levels equivalent to 2100 baseline SLR (Bouhafs, 2026).

Conclusion

The coastal archaeological heritage of Tipaza represents an irreplaceable cultural legacy facing severe climate and erosive risks. As spatial modeling under IPCC scenarios demonstrates accelerating shoreline retreat and heightened sea-level rise by

2100, preserving these vulnerable deposits requires moving from reactive crisis measures to proactive resilience. Achieving this demands integrating interdisciplinary research, geospatial monitoring, marine buffer zone enforcement, and community stewardship.



Dr. Rafik Khellaf is an accomplished Professor of Archaeology and heritage expert specializing in coastal settlement dynamics, site protection, and ancient urban centers across North Africa. Holding an Accreditation to Direct Research (HDR) and a Doctorate from the University of Algiers 2, he serves as the founder and director of the Laboratory of Historical and Archaeological Studies (LEHA). Throughout his career, Dr. Khellaf has led numerous international research initiatives, terrestrial and underwater excavations and surveys, and preventive archaeology projects in collaboration with leading institutions such as CSIC and UNESCO networks. He has also served as President of the National Commission for Underwater Archaeology (CTNarcheo) and Editor-in-Chief of Tafza Journal. His extensive publication record spans coastal site vulnerability, ancient trade networks, and maritime cultural resource management.

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The Last Great Wilderness: Underwater Cultural Heritage and Climate Change in the Antarctic

Dragomir Garbov

The Antarctic Treaty area lying south of 60°S (**Fig. 1**), contains significant but poorly characterised underwater cultural heritage (UCH). Shipwrecks represent successive phases of human activity, ranging from nineteenth-century exploration and sealing to twentieth-century whaling, polar exploration and science. Although numerous wrecks are historically documented (Headland 2009), underwater archaeological investigations remain limited. While observations at a small number of wooden wrecks, including the large sailing vessel designated as Historic Site and Monument No. 74 (HSM-74) and Ernest Shackleton's Endurance (1915; HSM-93), suggest

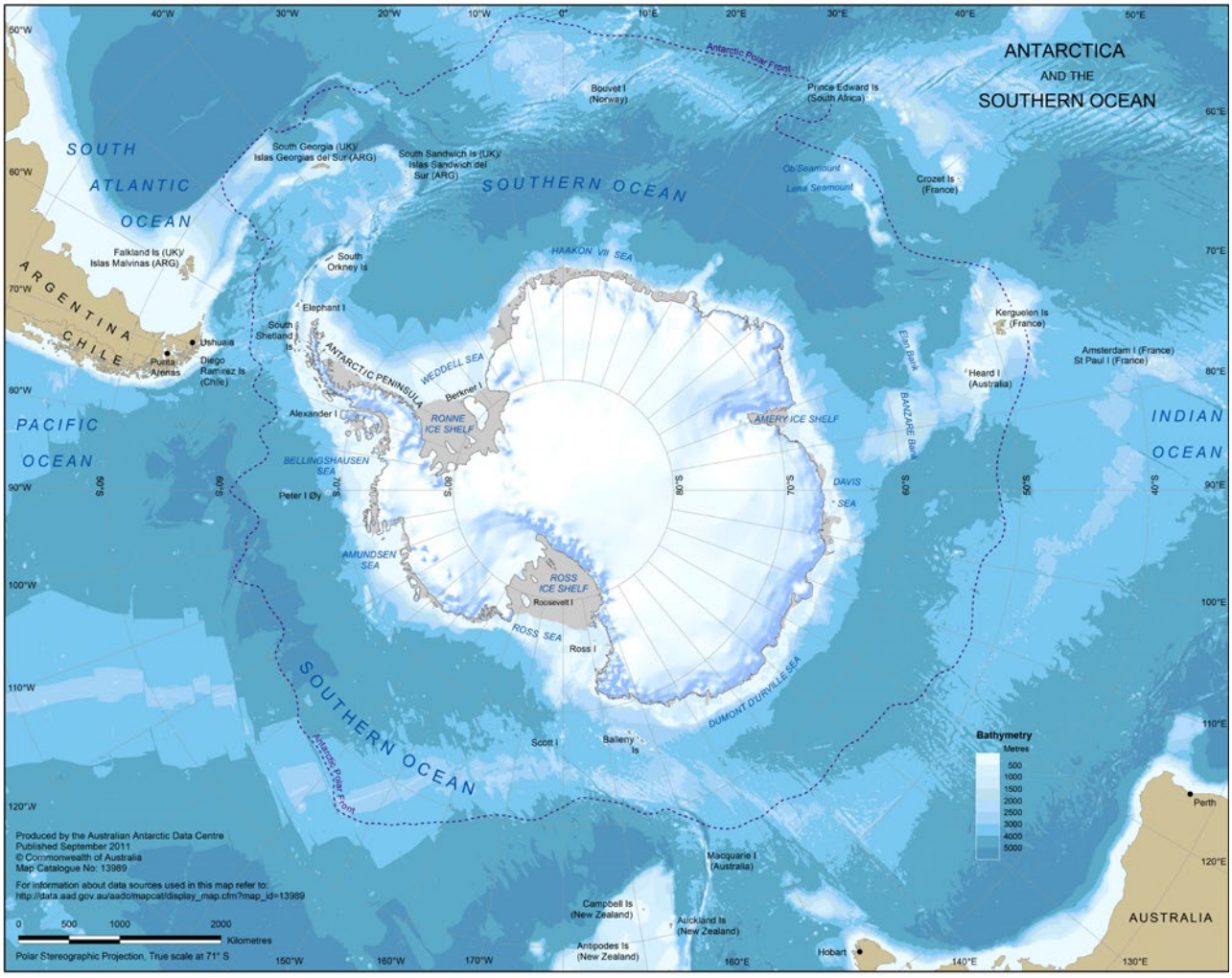


Figure 1- Antarctica and the Southern Ocean (Australian Antarctic Division; Map No. 13989; Sep. 2011).

potential for exceptional preservation comparable with that of the Canadian Arctic. However, the extent, distribution and condition of Antarctic UCH remain poorly understood. This knowledge deficit presents a significant management challenge as climate-driven environmental change alters preservation conditions.

Environmental change is pronounced on the Antarctic Peninsula and South Shetland Islands, where much of the known and potential Antarctic UCH is concentrated. The Peninsula is warming faster than the global average. At Vernadsky Station, temperatures increased by 0.45 ± 0.19°C per decade between 1951 and 2024, compared with approximately 0.2°C globally since the late 1970s (Davies *et al*. 2026). Long-term observations from Livingston and Deception islands similarly document substantial climatic change (González-Herrero *et al*. 2026). At Potter Cove, King George Island, summer surface-water temperatures increased by approximately 0.36°C per decade between 1991 and 2009, accompanied by declining sea-ice and increased glacial influence on hydrography and sedimentation (Schloss *et al*. 2012). Glacial retreat has further modified benthic communities and seabed biogeochemistry (Sahade *et al*. 2015; Jerosch *et al*. 2018). Changes of such magnitude have significant potential to affect the condition of submerged archaeological material.

Antarctic UCH comprises a diverse archaeological record. Its earliest component may potentially be the Spanish 74-gun ship-of-the-line *San Telmo*, declared as HSM-95, albeit of unknown location, which was lost without a trace in 1819 and subsequently sought around Livingston Island without definitive identification (Martín-Bueno 1995, 1996; Martín-Cancela 2018). The rapid expansion of sealing (**Fig. 2**) in the following years resulted in numerous losses, including at least six vessels in the South Shetlands between 1820 and 1822: the British brigs *Hannah*, *Lady Troubridge*, *Cora* and *Robert*, and the American barque *Clothier* and brig



Figure 2- James Weddel's brig Jane and cutter Beaufoy passing 74°S on 20 February 1823 (hand-coloured lithograph, Edward Duncan; William John Huggins, 1839; image: public domain). In the 1820s, British and American fur sealers became pioneers of Antarctic exploration.

Venus (Pearson 2018; Garbov 2026). While archival sources point to the approximate locations of these wrecks, their respective remains have not been identified.

This is the case for the majority of historic wrecks in Antarctica. Of the 27 pre-twentieth-century vessel losses identified in Richardson's (2020) desk-based assessment of UCH in the British Antarctic Territory and Southern Ocean, 25 (92.6%) remain unlocated. While in other maritime regions, archaeological sites are frequently identified incidentally through fishing, diving and marine development, the relative scarcity of such activities in Antarctica limits opportunities for chance finds. Discoveries nevertheless occur. In 1998, the UK Ice Patrol Vessel *Endurance* located a wooden wreck off Hampson Cove, Elephant Island, subsequently designated as HSM-74 (ATCM 1998, M2). Initially associated with the steamer *Hampson*, the wreck has more convincingly been associated via dendrological analysis with the American sealer *Charles Shearer*, lost in 1877 (Zarankin *et al*. 2023). This demonstrates that the small number of located wrecks in Antarctica reflects limited archaeological investigation rather than the extent or distribution of Antarctic UCH.

Later maritime industries produced further archaeological evidence ranging from individual sites to complete landscapes. Industrial whaling left significant coastal and submerged remains around the Antarctic Peninsula and the South Shetlands. The Norwegian whaling factory ship *Guvernøren* (**Fig. 3**), burnt and wrecked in Foyn Harbour in 1915, survives as a substantial iron wreck and is now becoming a prominent tourist and diving attraction. The former whaling station at Deception Island is associated with a number of preserved wooden boats and maritime infrastructure (**Fig. 4**). Examples of later iron and steel wrecks include the Norwegian whale catcher *Bransfield*, lost in 1924 somewhere off Livingston Island (Richardson 2020, Appendix 2).

At the opposite end of the spectrum is the famous wreck of Shackleton's *Endurance*, lost in the same year as the *Guvernøren* (1915) and found in the Weddell Sea in 2022 (**Fig. 5**). Its designation as HSM-93 encompasses the wreck and a 500 m protected area. The *Endurance Conservation Management Plan* provides the most developed Antarctic UCH framework, prioritising non-destructive investigation, recognition of the wreck's ecological context, assessment of long-term environmental pressures, and management of research and access (UK Antarctic Heritage Trust & Historic England 2024). *Endurance*, however, is an exception. For most Antarctic UCH environmental and condition baselines are absent, which precludes systematic assessment of climate-related risk.

Climate-related impacts on UCH are understood as both cumulative and interacting (Sesana *et al*. 2021; Gregory *et al*. 2022). Changes in sea level, coastal erosion, storm regimes, ocean temperature, acidification, oxygenation and biological activity can modify preservation and site formation. Evidence from the South Shetlands and the Antarctic Peninsula demonstrates that climate change is transforming coastal marine environments. Glacial retreat and meltwater discharge are modifying hydrography, sedimentation and benthic conditions (Schloss *et al*. 2012; Sahade *et al*. 2015; Jerosch *et al*. 2018). At Potter Cove, meltwater-derived terrigenous sediment affects seabed composition and biogeochemical conditions (Jerosch *et al*. 2018). Southern Ocean warming and associated changes in circulation and meltwater



Figure 3- The wreck of the Guvernøren in Foyn Harbour, Nansen Island (credit: Christopher Michel; images: public domain).



Figure 4- Remains of Norwegian whaleboats on Deception Island (credit: Christopher Michel; image: public domain).



Figure 5- The stern of the Endurance with the name and emblematic polestar (credit: Falklands Maritime Heritage Trust and National Geographic; image: public domain).

inputs (Cai *et al*. 2023) further underline the need for site-specific environmental baselines to assess how these processes affect the preservation of Antarctic UCH.

Future projections indicate further substantial environmental change in Antarctica. Although increased accumulation on the East Antarctic Ice Sheet is projected for this century, Stokes *et al*. (2022) suggest that continued high emissions beyond 2100 could accelerate ice discharge, contributing several metres to global sea-level rise within a few centuries, if warming exceeds the Paris Agreement's 2°C threshold (see also DeConto *et al*. 2021). The IPCC's Sixth Assessment Report projects continued ocean warming under all assessed emissions scenarios, with best estimates of global surface warming for 2081–2100 relative to 1850–1900 ranging from 1.4°C under very low emissions (SSP1-1.9) to 2.7°C under intermediate emissions (SSP2-4.5) and 4.4°C under very high emissions (SSP5-8.5) (IPCC 2023). Regional modelling also projects acidification of Antarctic coastal waters across the emissions scenarios examined and accelerated Amundsen Sea warming even under strong mitigation (Naughten *et al*. 2023; Nissen *et al*. 2024). Although these projections cannot directly predict deterioration at individual Antarctic shipwrecks (due to lacking baseline data), they reinforce the need to assess UCH vulnerability across a range of future conditions rather than assume that existing preservation environments will remain stable.

Managing Antarctic UCH therefore requires site-specific vulnerability data on material composition, exposure and burial, sediment dynamics, hydrodynamics and biological activity. The absence of baseline survey data for all Antarctic wrecks, but the *Endurance,* indicates that inventory and baseline documentation should be regarded as the first climate-adaptation measures to be undertaken as prerequisites for evidence-based management. Risk cannot be prioritised where sites remain unidentified, nor can deterioration be detected without condition data. This accords with the ATCM *Guidelines for the Assessment and Management of Heritage in Antarctica*, which incorporate climate vulnerability, environmental risk, monitoring and adaptation into conservation management planning (ATCM 2022).

The immediate priority should therefore be a systematic Antarctic UCH inventory integrating archival research, spatial data and non-invasive archaeological survey. Australia has taken an initial step by incorporating shipwreck records for the Australian Antarctic Territory and Heard Island and McDonald Islands into the Australasian Underwater Cultural Heritage Database, providing a foundation for targeted survey and baseline assessment (Garbov and Norris 2026; Garbov and Norris in this volume). Antarctic Treaty Parties that recognise the principles of the 2001 UNESCO *Convention on the Protection of the Underwater Cultural Heritage* and maintain national Antarctic programmes are particularly well placed to undertake this work. Existing scientific and logistical capacity could support fieldwork consistent with Antarctic Treaty System requirements and the Annex to the 2001 Convention (UNESCO 2001; ATCM 2022). Surveys should prioritise non-invasive investigation and documentation, while cooperation between national programmes could extend capacity across the continent. Marine geophysics and remotely operated vehicle (ROV) and autonomous underwater vehicle (AUV) surveys can establish site locations; photogrammetric recording and diving assessments can provide repeatable condition baselines. Integrating archaeological and environmental observations would allow site changes to be assessed against changing marine conditions. This evidence base can support a staged, risk-based approach progressing from inventory and significance assessment to vulnerability assessment, risk prioritisation, and targeted monitoring or intervention. As comprehensive intervention across Antarctic UCH is neither practicable nor desirable, management effort should focus on sites where significance and vulnerability indicate the greatest potential loss.

Considering preservation *in situ* as the first option should remain the default approach, consistent with the Annex to the 2001 UNESCO Convention and the management principles applied to *Endurance* (UNESCO 2001; UK Antarctic Heritage Trust & Historic England 2024). In a rapidly changing environment, however, preservation cannot be equated with passive non-intervention as sufficient information is required to determine whether the environmental conditions supporting preservation remain stable. Monitoring and limited intervention where required are therefore integral components of preservation.

Climate change exposes a fundamental limitation in Antarctic UCH management: the absence of a systematic evidence base beyond a single prominent site. In a rapidly changing environment, a continent-wide inventory linked to condition and environmental vulnerability data would be a stable prerequisite for climate adaptation. The objective is to identify and systematise significant UCH, assess vulnerability, and detect change before archaeological information is irreversibly lost. As for all UCH globally, climate adaptation must begin with knowledge of the resource.

Institute of Nautical Archaeology

The Institute of Nautical Archaeology (INA) is committed to locating, excavating, recording, preserving, and publishing shipwrecks and other archaeological sites of maritime significance all over the world. INA is a non-profit, international research organization founded in 1972 by Dr. George F. Bass †, who pioneered the science of archaeological excavation under water.



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Dragomir Garbov's research interests focus on wooden shipbuilding and seafaring during the Golden Age of Sail, with a particular emphasis on the Black Sea, the Pacific and Southern Oceans, and Antarctica.
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In 2026, he led the preparation of the first underwater cultural heritage assessment of the Heard Island and McDonald Islands. He also holds a range of recreational and commercial diving qualifications, supporting his extensive fieldwork in maritime and underwater archaeology.

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Climate Change Impacts on Underwater Cultural Heritage in Northern Patagonia, Argentina: Quantifying Environmental Risks for data-driven management

Alessandra Bonazza, Alessandro Sardella, Virna L. Meccia, Mónica Grosso, Julieta Frère, and *Dolores Elkin*

Introduction

Since results of the first European Union (EU) project funded in the topic (Noah's Ark) were published, the nexus between climate change and cultural heritage protection has gained considerable attention within scientific discussion (Sabbioni *et al*. 2010). The scientific community and public institutions and authorities, have increasingly recognized that both slow-onset climate variations and extreme hydrometeorological events pose unprecedented threats to cultural assets across diverse spatial contexts. However, despite unquestionable scientific progress, a significant disconnection still persists between theoretical research, policy integration, and actionable management strategies on the ground. At the governance level, cultural heritage remains remarkably under-represented in broader climate adaptation agendas and Disaster Risk Reduction frameworks. A primary driver of this implementation gap is the inefficient translation of academic research into concrete, user-friendly tools designed to assist heritage managers and policy-makers, in defining acceptable risk thresholds and prioritizing resource allocation (European Commission 2018; 2022).

Beyond these institutional shortfalls, existing scientific literature exhibits a marked methodological and sectoral asymmetry. Research to date has focused overwhelmingly on terrestrial and subaerial built heritage (e.g., stone, marble, mortar, and metallic elements in urban, rural, or coastal environments). In these terrestrial settings, substantial efforts have gone into formulating quantitative damage functions, establishing dose-response relationships, and applying regional climate models to project cumulative damage due to gradual changes of climate and air quality and impacts induced by climate extreme hazards in near and far-future scenarios (Sesana *et al*. 2021; Bonazza and Sardella 2023; Romero-Rojas *et al*. 2026).

In contrast, Underwater Cultural Heritage (UCH) — encompassing shipwrecks and other partially or totally submerged archaeological sites as well as submerged landscapes — remains largely underexplored within evaluations of projected climate modelling frameworks. What remains critically lacking is a comprehensive, multi-scalar understanding of how climate projections will alter the subtle physico-chemical and biological equilibriums governing deeper or shallow marine ecosystems (Meccia *et al*. 2026).

This chapter addresses this research gap by examining the impacts of changes in sea surface temperature, sea surface salinity, ocean acidification and ocean oxygenation on submerged sites in Northen Patagonia. By analysing future projections, the study evaluates how these environmental stressors contribute to accelerating the degradation of submerged archaeological materials, such as wood and metals, which are the main components of ship´s hulls, and represent most of UCH. This work aims to provide a framework for integrating UCH into broader climate change adaptation strategies, moving beyond qualitative descriptions toward data-driven risk management.

Underwater Cultural Heritage in Northern Patagonia

The record of human presence on the Patagonian coast dates to approximately 11,000 years ago (Otero *et al*. 2026). Nomadic hunter-gatherer populations exploited marine resources as part of their subsistence. Archaeological remains include stone structures interpreted as possible fish traps, although their function and chronology remain uncertain. To date, no evidence of Indigenous navigation has been identified so far.

Since the 16th century, vessels of different origins have navigated the region in the context of exploration, colonization, commerce, extractive activities, and warfare. Nautical accidents were frequent on the Patagonian coast throughout this intense seafaring period, due to challenging maritime conditions, harsh weather, and limited coastal infrastructure or navigation aids. Several hundred shipwrecks occurred along the Patagonian coast and surrounding archipelagos between the early 17th century and mid-20th century CE (Elkin 2019). To date, only a small number of these have undergone archaeological assessment (Elkin *et al*. 2015; Grosso *et al*. 2026).

UCH recorded to date in Northern Patagonia is mainly characterised by post-18th-century CE shipwrecks (**Fig. 1**). The predominant remains comprise wooden and metal (hulls, nautical remains) as illustrated by the examples from northern Chubut Province (**Fig. 2** and **Tab. 1**). Sandy bottoms prevail, so in some cases shipwrecks are partially covered by sediment, which contributes to their preservation. Exposed remains are susceptible to various forms of physicochemical and biological deterioration, including significant damage caused by marine wood-boring organisms (Meccia *et al*. 2026).

Projected Impacts of Climate Change on UCH in Northern Patagonia

The latest generation of Earth System Models, developed within the sixth phase of the Coupled Model Intercomparison Project (CMIP6), were used

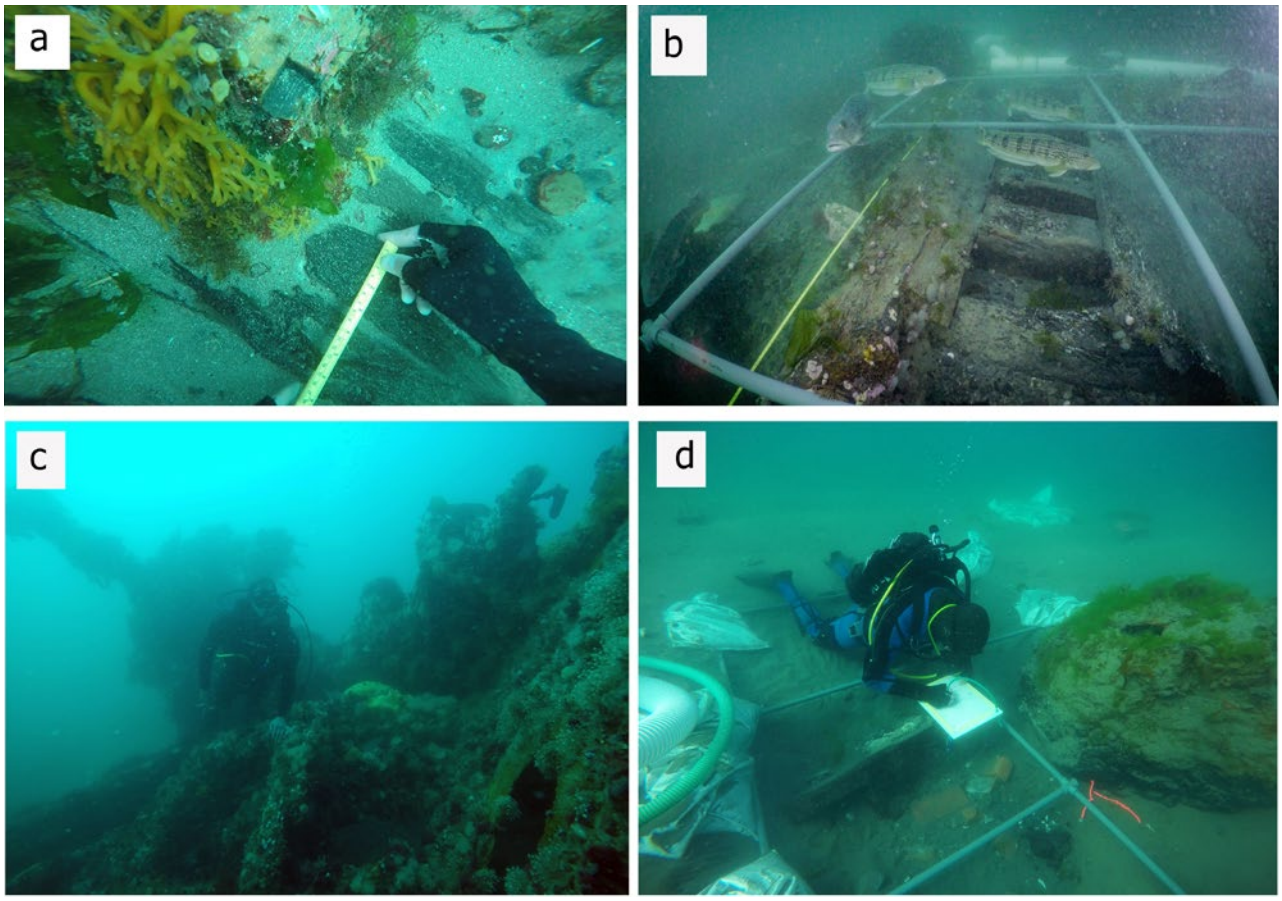


Figure 1- A selection of shipwreck sites in northern Patagonia. (a) Caleta Inglesa (19th century CE), photo: C. Murray; (b) Emma (1883–1945), photo: U. Sokolowicz; (c) Flora (1895–1925), photo: U. Sokolowicz; (d) Bahía Galenses (mid-19th century), photo: M. Grosso.

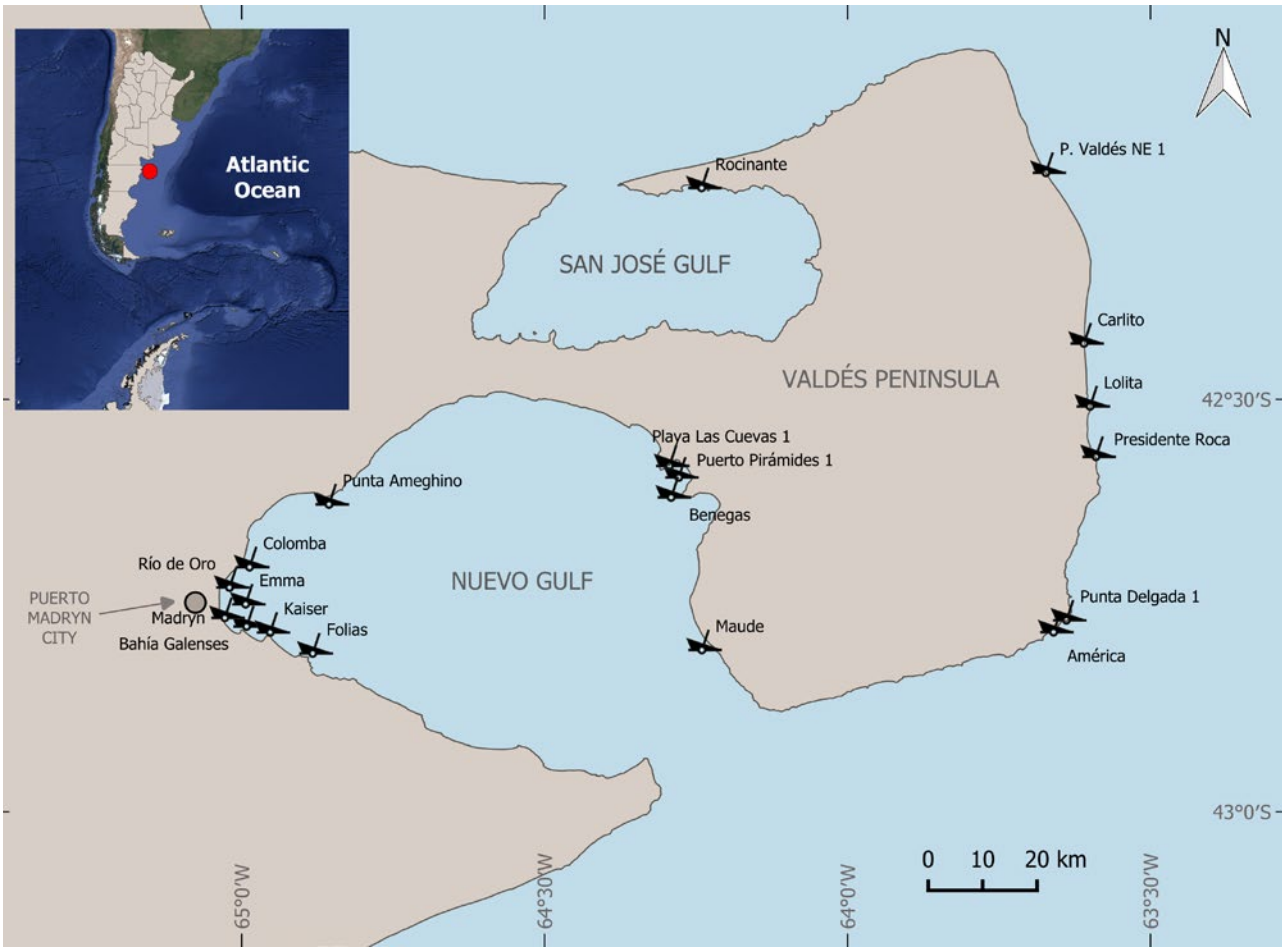


Figure 2- Known shipwreck sites on the northern coast of Chubut Province. Map: C. Murray.

to assess how climate conditions may change under the Shared Socioeconomic Pathway 5-8.5 (SSP5-8.5) over the period 2015–2100 (**Fig. 3**, **Tab. 2**). Known as the Fossil-Fuelled Development scenario, SSP5-8.5 represents a future characterized by rapid economic growth and a strong reliance on fossil fuels. To establish a baseline for present-day conditions, historical CMIP6 simulations covering 1950–2014 were also used, which account for observed climate drivers. Four models with a horizontal resolution of 1 degree in the ocean, are included in the analysis (see Table 4 in Meccia *et al.* 2026).

Available research and projections highlight what UCH in Northern Patagonia is likely to expect in the far future period (2071-2100) under SSP5-8.5 scenario:

- higher rates of biodegradation of wooden components than historically observed and consequently weakening of the hull remains (in case of wooden shipwrecks) caused by a projected temperature increase to around 17.7% by the end of the century. A temperature rise of this magnitude would be associated with a significant energizing of electrochemical corrosion rates of metallic structures and the metabolic activity of biodeteriogens;
- acceleration of corrosion of metallic structures and destabilization of protective calcareous concretions due to a projected pH decrease of about 4.5% by the end of the century. Ocean acidification would likely further intensify the degradation of wood and metal structures both by diminishing protective calcifying species and by promoting acid-secreting soft-bodied organisms.

Dissolved oxygen is projected to drop due to rising sea surface temperatures, though not enough to create protective anaerobic conditions in case of wooden shipwrecks. Consequently, the severe destabilizing impacts of increased temperature

Shipwreck site	Vessel chronology	Typology	Hull material	Setting (depth)
Rocinante	18th c.	Unknown	Wood	Subtidal (8m)
P. Valdés NE 1	19th c.	Unknown	Wood	Intertidal
Benegas	19th c.	Unknown	Unknown	Subtidal (16m)
Bahía Galenses	Mid 19th c.	Sailing vessel	Wood	Intertidal / Subtidal
Puerto Pirámides 1	19th-early 20th c.	Sailing vessel	Wood	Intertidal
Playa Las Cuevas 1	19th-early 20th c.	Unknown	Wood	Intertidal
Maude	1850-1914	Steamship	Iron/steel	Intertidal
Emma	1883-1947	Schooner with propeller	Wood	Subtidal (16m)
Kaiser	1891-1915	Steamship	Iron/steel	Intertidal
Presidente Roca	1896-1909	Steamship	Steel	Intertidal
Río de Oro	2nd half 19th c.-1918	Schooner	Wood	Subtidal (18m)
Lolita	Late 19th c.-1905	Schooner	Iron	Intertidal
Colomba	Late 19th c.-1935	Schooner with propeller	Iron/steel	Intertidal
Punta Ameghino	Late 19th c.-1938	Barge	Iron/steel	Subtidal (4m)
Madryn	1911-1944	Steam tug	Iron/steel	Subtidal (4m)
América	1920-1937	Steamship	Steel	Subtidal
Carlito	Early 20th c.-1940	Schooner with propeller	Iron	Intertidal
Punta Delgada 1	20th c.	Unknown	Wood	Intertidal
Folias	1967-1980	Fishing trawler	Steel	Subtidal (8m)

Table 1- Main characteristics of the shipwreck sites shown in Figure 2.

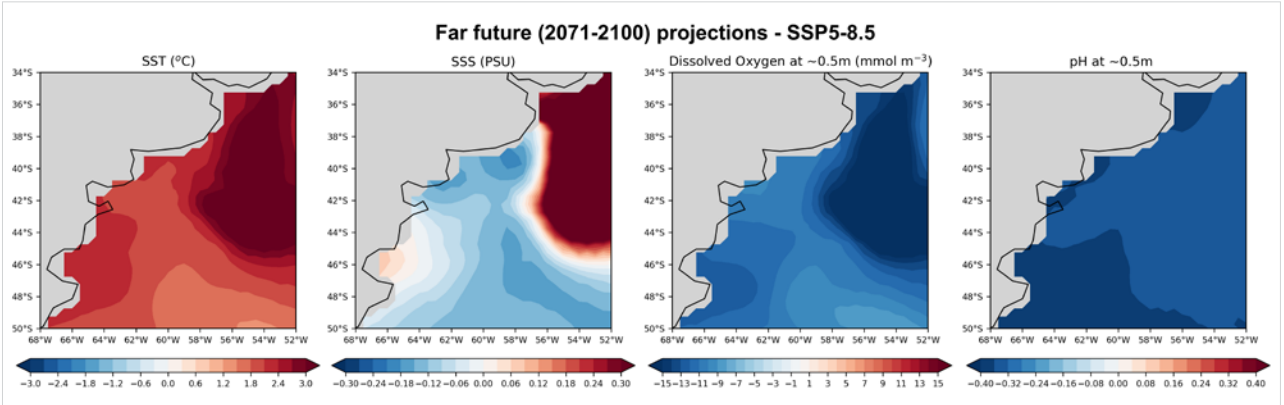


Figure 3- Anomaly fields of the CMIP6 ensemble mean Sea Surface Temperature (SST, °C), Sea Surface Salinity (SSS, PSU), near-surface Dissolved Oxygen (DO, mmol m-3) and near-surface pH. Fields are shown for the far-future period (2071–2100) under the SSP5-8.5 scenario. Adapted from Meccia et al*. 2026.*

Parameter	Far Future – SSP5-8.5
SST (°C)	2.067 (17.72%)
SSS (PSU)	-0.079 (-0.23%)
Dissolved Oxygen at ~0.5m (mmol m^{-3})	-11.161 (-3.98%)
pH at ~0.5m	-0.363 (-4.49%)

Table 2- Absolute future changes (and corresponding percentage changes) in the environmental variables relative to the historical period in Northern Patagonia (50°S-40°S; 68°W-60°W). Results are presented for the far future time period and under SSP5-8.5 scenario.

and ocean acidity will easily outweigh any minor protection from reduced oxygen levels. Meanwhile salinity shifts remain negligible across all scenarios (< 0.25%), making it the least affected environmental variable.

The results presented here represent the most pessimistic scenario; however, the overall trends remain consistent under more moderate scenarios and shorter time horizons, as demonstrated in Meccia *et al*. (2026).

Acknowledgments

We wish to thank Hakan Öniz and Laro González Canoura for their kind invitation to be part of this book project. This international collaboration was conducted in the frame of EU H2020 MSCA project TECTONIC (Grant ID 873132).



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Rising Seas, Local Solutions: Climate Change and the Fortified Maritime Cultural Landscape of Cartagena de Indias (Colombia)

Carlos Del Cairo Hurtado, Jesús Aldana Mendoza, Gabriela Caro León, Victoria Báez Santos, Carla Riera Andreu, Liliana Rozo Pinzón, Juan David Sarmiento Rodríguez, and *Juliana Quintero Hernández.*

Introduction: Threats of Climate Change to Coastal and Underwater Cultural Heritage in the Colombian Caribbean

Cartagena de Indias, located on the Colombian Caribbean coast, has historically been a stronghold of great importance since the 16th century, when the Spanish recognized it as a strategic site for the defense of their economic and military interests. Gradually, the area began to take shape with military and civilian structures designed to defend the city, which were put to the test during various enemy sieges: as was the case in 1586 against the English, in 1697 against the French, and in 1741 once again against the English. For more than three centuries, fortifications of various sizes and shapes were built, generally located in coastal areas, to ensure at all costs the continued Spanish presence in what is now Colombian territory.

With so much effort devoted to this end, including the adaptation of the living environment, a Fortified Maritime Cultural Landscape began to take shape in Cartagena de Indias, dedicated for decades and centuries to protecting this valuable territory. The objective was achieved, as no enemy power ever conquered the city, the Spanish maintained their territorial control, and the region's fortifications and other defensive infrastructure withstood foreign assaults. However, due to the pressures exerted by human activity on global atmospheric dynamics since the Industrial Revolution, coupled with natural climate variations occurring with increasing intensity, this landscape has exhibited serious vulnerabilities (Báez *et al*., 2026; Del Cairo & Caro, 2026).

Inevitably, the Coastal and Underwater Cultural Heritage of Cartagena de Indias, which was once used to safeguard the city and preserve it as it stands today (having been designated a World Heritage Site by UNESCO in 1984), has been exposed to serious threats caused by climate change. These include sea-level rise, heat waves, coastal flooding, coastal erosion, extreme precipitation, storm intensification, and other changes in seawater. Regarding these threats, their magnitude and variability differ across climate change scenarios and through interactions with non-climatic factors affecting the territory. The prospective assessment for Cartagena de Indias indicates that coastal erosion and coastal flooding are the most climate-sensitive hazards, with the number of sites at very high risk doubling between scenarios for the 2040 and 2060 horizons. In contrast, heat waves and extreme precipitation exhibit more moderate increases (Del Cairo & Caro, 2026).

These trends highlight the vulnerability of heritages located along the coastline, including fortifications, bastions, breakwaters, and other defensive structures. Their exposure to marine processes places them on particularly sensitive risk trajectories, especially in the most exposed coastal sectors. Consequently, future heritage management strategies should prioritize these areas and account for the differentiated impacts of climate change across hazards and locations (Del Cairo & Caro, 2026).

However, the configuration of risk in Cartagena de Indias does not depend exclusively on climatic factors. One of the distinctive characteristics of the territory is that relative sea-level rise is driven by both global processes associated with climate change and local geological and anthropogenic factors (Del Cairo & Caro, 2026). Among the latter, land subsidence stands out, being linked to natural processes as well as sediment compaction resulting from coastal urban development. This situation implies that a substantial portion of the risks currently faced by the city cannot be mitigated solely through global emissions-reduction strategies, but instead requires locally targeted interventions aimed at addressing the specific conditions of the territory (Del Cairo & Caro, 2026). In recent years, scientific research has been conducted to develop transdisciplinary analyses of this specific and challenging issue (Báez *et al*., 2026). All of this is based on a clear premise: it is not possible to analyze and mitigate the impacts of climate change on this heritage site without collaborating with local communities, who live among and interact with these heritage sites on a daily basis (Del Cairo & Caro, 2026). (**Fig. 1**).



Figure 1- Location of Cartagena de Indias and Map of Its Fortified Maritime Cultural Landscape (Map by the authors, photographs by Michael Snyder).



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Climate Change: Challenges and Opportunities for Monitoring and Mitigating Impacts on Heritage

Gradually, the city's Coastal and Underwater Cultural Heritage has been exposed to serious impacts and damage caused by variables and phenomena

associated with climate change. Military and civilian structures, including forts, walls, breakwaters, shipwrecks, production infrastructure, human settlements, docks, and piers, among others, have been severely impacted by the aforementioned threats, resulting in their partial or total loss. Some are now completely submerged, others partially so, and those that were already submerged are becoming more exposed and vulnerable to these climate variations. The challenges were more than evident, presenting a unique analytical and research opportunity to monitor and mitigate these serious impacts (Del Cairo *et al*., 2025).

Since 2023, an interdisciplinary team led by the NGO "Fundación Colombia Anfibia," with ongoing support from local communities and government agencies responsible for this heritage, has conducted three major research projects on the subject in Cartagena de Indias. First, the initiative called "Colaborartorio Azul," which has consisted of two phases: on the one hand, to identify, systematize, and interpret the effects of climate change on local maritime heritage; and on the other hand, to formulate a proposal for co-participatory assessment and monitoring of these effects (Del Cairo *et al*., 2023; 2025; Caro *et al*., 2026). Second, a project focused on understanding the link between the Anthropocene and climate change and how the traces of hyperobjects affecting the city's coastal heritage can be recorded and studied (Aldana et al., 2026).

Third, and most recently, the study "Preserving Legacies: Creating a Future for Our Past," conducted in collaboration with the International Council on Monuments and Sites (ICOMOS), the National Geographic Society, the Climate Heritage Network, and the NGO "Grupo Conservar." This research project focused primarily on applying local knowledge to develop mitigation and adaptation strategies to address the impacts of climate change, as well as on assessing the risks and impacts of this phenomenon on cultural heritage to plan for comprehensive adaptation that can be implemented in this Fortified Maritime Cultural Landscape (Del Cairo *et al*., 2026). Each of these initiatives has provided a unique opportunity to compile data on this particular climate situation and to explore how local knowledge can be integrated as a key and fundamental element in developing and implementing future solutions. (**Fig. 2**).



Figure 2- Impacts of Climate Change on the City's Heritage Sites (Photographs by Michael Snyder and Carlos Del Cairo).

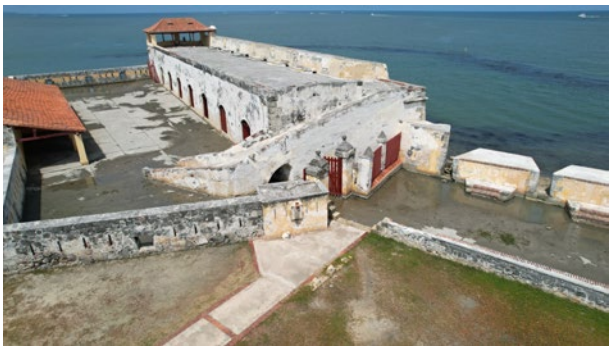


Figure 2- Impacts of Climate Change on the City's Heritage Sites (Photographs by Michael Snyder and Carlos Del Cairo).



Figure 2- Impacts of Climate Change on the City's Heritage Sites (Photographs by Michael Snyder and Carlos Del Cairo).

Final Considerations: Solutions to Protect the Fortified Maritime Cultural Landscape of Cartagena de Indias

Based on all of the above, a key question arises: How can we propose solutions to these risks that serve as best practices and truly help mitigate



Figure 2- Impacts of Climate Change on the City's Heritage Sites (Photographs by Michael Snyder and Carlos Del Cairo).

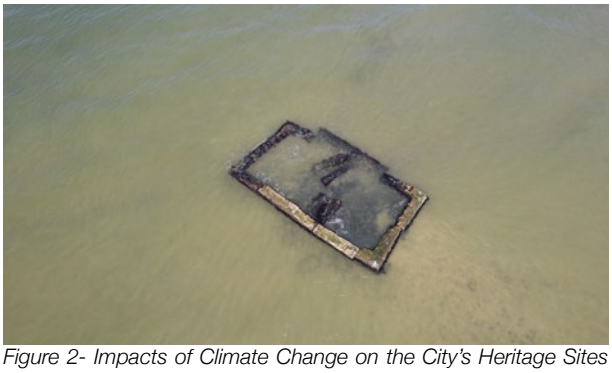


Figure 2- Impacts of Climate Change on the City's Heritage Sites (Photographs by Michael Snyder and Carlos Del Cairo).

the impacts of climate change on coastal and underwater heritage sites? Research conducted to date has made it possible to establish interpretive and action frameworks for this purpose. At the same time, during the course of these studies, a planning, management, and heritage safeguarding instrument was formulated and approved, known as the Special Plan for the Management and Protection of the Bay of Cartagena de Indias (Pemp Fort Bahía). This is a mandatory government tool designed to promote the long-term sustainability of heritage assets and contexts. In light of the serious threats posed by climate change to the city, and especially to its Fortified Maritime Cultural Landscape, which has been shaped over centuries, the PEMP incorporated a focus on climate change into its plans, programs, and action projects (Del Cairo *et al*., 2026).

In this regard, academic research, together with territorial management tools employed by government agencies, defined the course of action to establish solutions to these threats, along with the challenges and opportunities they present. The answer was clear: local communities had to play a leading role in both the short and long term to monitor the effects, mitigate the impacts, and implement the necessary solutions to protect this landscape and the heritage resources that comprise it (Del Cairo *et al*., 2023; 2025; 2026; Caro *et al*., 2026). Among the main solutions, which have also included support for research efforts, are:

- Joint co-production of knowledge to collect and process data.
- Participatory identification and approaches to understanding this phenomenon.
- A collaborative proposal for jointly measuring impacts.
- Use of social media to present and discuss the measurements taken.
- Implementation of analytical matrix to systematize the data.
- Support for archaeological excavations and surveys.
- Analysis of changes in the coastline based on historical maps.
- Historical reconstructions of climatic conditions.
- Photo-ethnographic analyses using old newspaper clippings. (**Fig. 3**).

Certainly, the goal is to turn local communities into generators of scientific knowledge while, at the same time, enabling them to act as decision-makers. These efforts have only recently begun. Assessing their true impact will take time to determine what has been effective and what can eventually be improved. If we truly want our past to have a future, it is absolutely essential to understand that solutions are, and must be, local; naturally with the support of the academic, private, and government sectors. Ultimately, it is the people who interact with and live alongside these Coastal and Underwater Heritage sites on a daily basis who can protect and safeguard them. Ensuring through their agency the comprehensive preservation of the Fortified Maritime Cultural Landscape of Cartagena de Indias for the future.



Figure 3- Workshops and Participatory Initiatives with Local Communities (Photographs by Michael Snyder).



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We are an interdisciplinary of experts in archaeology, anthropology, conservation, restoration, and history. We hold undergraduate and graduate degrees and have extensive experience in the management, research, and preservation of cultural and archaeological heritage in Colombia. Organization endorsed by Ocean Decade.
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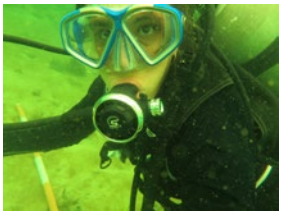
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Climate Change and the Preservation of Freshwater Shipwrecks – Lake Champlain as Case Study

Carolyn Kennedy and *Liz Trevino*

While climate change's adverse effects on our marine and coastal archaeological sites are being widely studied, as evidenced by the many chapters in this volume, what impacts are taking place in our freshwater ecosystems are just beginning to be observed. Freshwater shipwrecks are often among the best preserved due to the low salinity in the water, and in the case of Lake Champlain (and the Great Lakes), their northernly climate and cold waters contribute to above average preservation (**Fig. 1**). Lake Champlain alone holds over 300 historic shipwrecks, only a handful of which have been extensively studied. Those that have been studied have contributed greatly to our understanding of historic shipbuilding due to that same excellent preservation (**Fig. 2**) (Crisman, 2014).

Anecdotal evidence from maritime archaeologists with decades-long careers in Lake Champlain described increased storm disturbance, erratic freezing and thawing, and greater numbers of cyanobacteria blooms as well as an onslaught of invasive species. These issues have been widely but indirectly attributed to climate change's broad effects. The question that emerged from these observations was how these factors will impact long-term shipwreck preservation in what has, thus far, proven to be an especially preservation-friendly environment.

A seed grant awarded by Texas A&M University (TAMU)'s Environmental and Sustainability Initiative (ESI) provided funding for research into this issue as well as a three-day convergence workshop hosted by TAMU's Center for Maritime Archaeology and Conservation (CMAC). The ESI-sponsored convergence workshop included faculty and students (undergraduate and graduate) from TAMU's Department of Anthropology's Nautical Archaeology Program (NAP) and TAMU's Department of Biology as well as experts and professionals from the Lake Champlain Maritime Museum (LCMM), the Lake Champlain Basin Program (LCBP), and the National Oceanic and Atmospheric Administration (NOAA)'s Thunder Bay National Marine Sanctuary. The workshop included presentations and roundtable discussions by experts from the above agencies in nautical archaeology, archaeological conservation, water chemistry and ecology, and biology. Discussions addressed the interdisciplinary nature of preserving wooden and metal cultural heritage materials – shipwrecks – in the changing water chemistry resulting from climate change.

To specifically address climate change's potential adverse effects on shipwreck preservation, four subthemes were identified as impacted by the environment and potentially detrimental to wood and metal degradation. These are 1) microbial activity; 2) storm severity; 3) chemical changes to the water; and 4) decreases in annual ice coverage.

1) Microbial activity intensifies at higher temperatures causing the structural stability of wooden shipwrecks to degrade more rapidly. Lake Champlain's average August surface water temperature has increased 3.8°C since the LCBP began monitoring in 1964 (Lake Champlain Basin Program [LCBP], 2026). Research on aquatic microorganisms has shown that rising temperatures affect microbial growth, reproduction, and adaptability (Wuebbles et al., 2021, p. 29). Although there is little to no literature directly discussing the climate-driven growth of Erosion Bacteria (EB) and

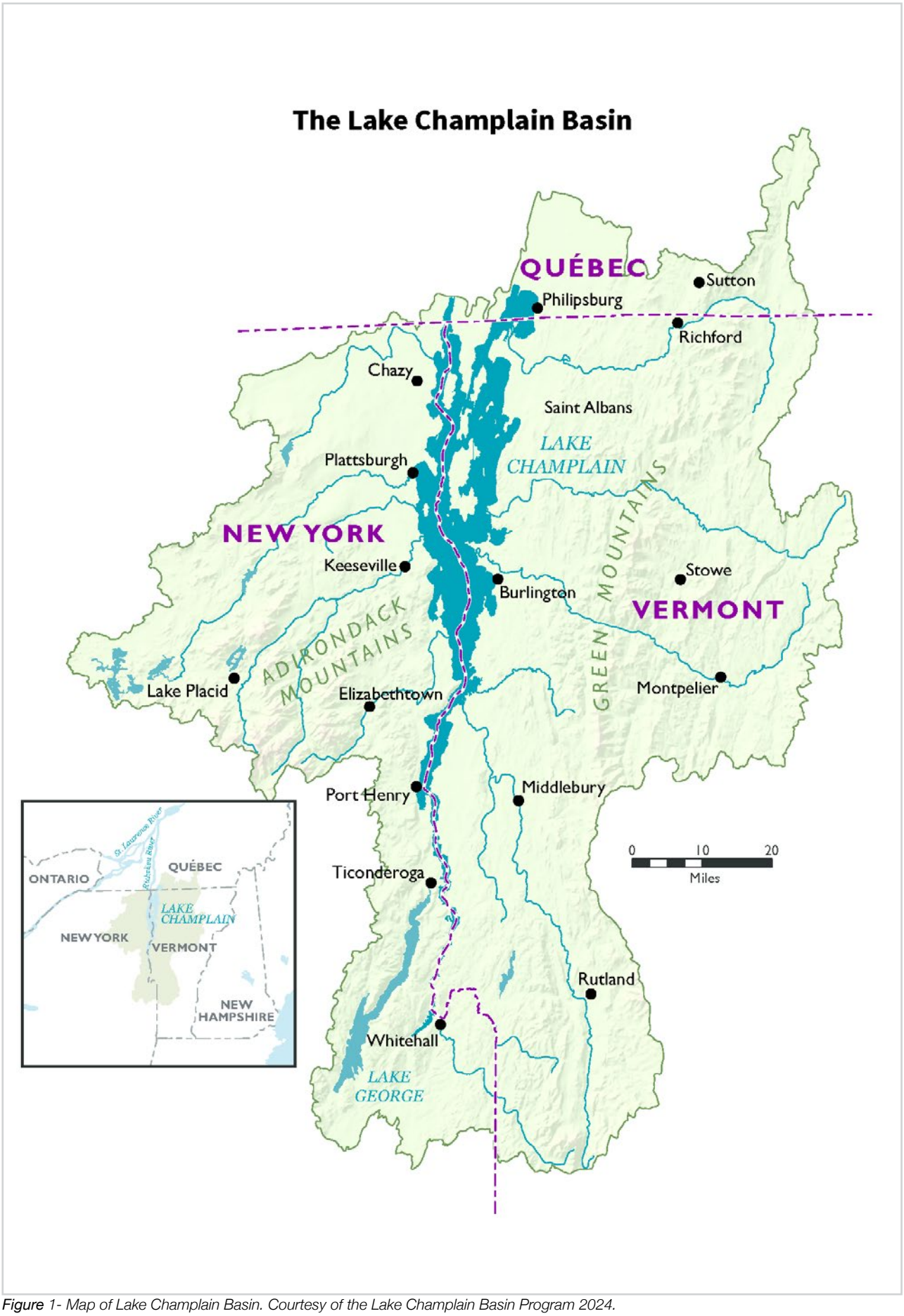


Figure 1- Map of Lake Champlain Basin. Courtesy of the Lake Champlain Basin Program 2024.



Figure 2- Hull of steamboat wreck Phoenix (1815-1819) resting at about 25 meters in Lake Champlain showing the excellent preservation of the almost 200-year-old wooden hull and metal fasteners. Photo by Pierre LaRocque, 2000. Courtesy of the LCMM.

soft-rot fungi, inferences can be drawn from the current influx of cyanobacteria in Lake Champlain. In the LCBP's 2024 State of the Lake and Ecosystem Indicators Report, there were relatively high cases of cyan blooms across the lake in 2023 (p.11). The LCBP associates the cause with the "increased periods of warm and calm weather," creating ideal conditions for bacterial growth. This accelerated microbial growth can degrade wood more rapidly, thereby affecting the preservation of shipwrecks.

2) Increased severity of storms can impact archaeological fieldwork and poses physical damage threats to weakened shipwrecks. GLISA, NOAA's Great Lakes Climate Adaptation Partnerships team, found a 55% increase in precipitation from the Northeast's heaviest 1% of storms between 1958 and 2016. Storm frequency and intensity have also increased and are expected to continue rising with climate change (GLISA, 2026). In 2024, after Hurricane Beryl, local divers on Lake Champlain noted that the visibility was the worst it had been in over 30 years. For maritime archaeologists, documentation of a site becomes longer and significantly more difficult if the site cannot be seen or cannot be accessed due to hazardous weather conditions. In general, physical damage to shipwreck hulls may occur due to sediment displacement and suspension, and even site shifting (**Fig. 3**).

3) In Lake Champlain, long-term chloride concentrations have increased, transported into the lake through snowmelt or rainfall runoff washing road salts (used to de-ice throughout the long winter seasons) into the lake. The annual average chloride concentration within Lake Champlain has risen between 20% and 54% since 1992 (LCBP, 2024, p.16-17). A continued rise in chlorides across freshwater lakes is expected as "interannual variability of seasonal snow coverage," which has surpassed 50% in the nearby Great Lakes, will make salinity changes difficult to track or predict without long-term monitoring (Zhao et al., 2025). Little is currently understood on how these small amounts (comparatively to marine environments) will impact shipwrecks. Some concerns may be changes to microbial and chemical processes and the ecological landscape of freshwater environments, leading to destabilization.

4) Seasonal ice coverage has decreased across the Great Lakes, with an analysis showing a 71% overall loss (Wang et al., 2012). Similar trends are emerging in nearby lakes, as projections indicate that by 2050, Lake Champlain will freeze only once a decade, compared to its annual freeze in 1910 (LCBP, 2024, p. 29). Reduced ice coverage may also have implications for invasive species. Typically, during winter months, biological activity tends to drop, leading to reduced proliferation in freshwater species, aiding in the preservation of freshwater wrecks. However, if invasive species are allowed to remain active for longer portions of the year, this may lead to increased expansion and colonization.

The consensus of the workshop was that, while our freshwater shipwrecks are likely not in immediate danger of disappearing, chemical, physical, and biological factors are causing their slow degradation, and while many of these exist in what the team has coined as a 'sphere of influence' upon which climate change is only one contributing factor, many of these issues will nonetheless be adversely affected by climate change.

To address these findings, our team developed a pilot monitoring program for climate-change-related degradation of Lake Champlain shipwrecks. The Pot Ash Point Canal Boat, a 19th-century wooden shipwreck with metal fasteners that is part of the Vermont Underwater Historic Preserves system, was selected for pilot monitoring and baseline data acquisition due to its relatively accessible depth and relatively minimal popularity among the diving public (**Fig. 4**) (The state of Vermont, largely through the LCMM, maintains twelve underwater historic sites that are seasonally open to the diving public to visit, see State of Vermont, n.d., and Lake Champlain Maritime Museum, n.d.).

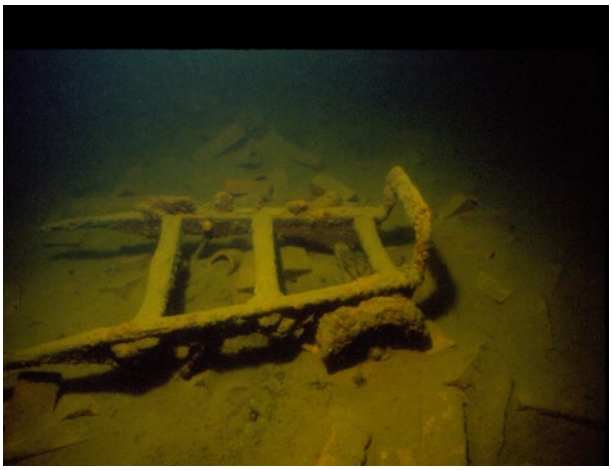


Figure 3- (a) Photograph of a hand truck from shipwreck O.J. Walker in Burlington Bay from 1980

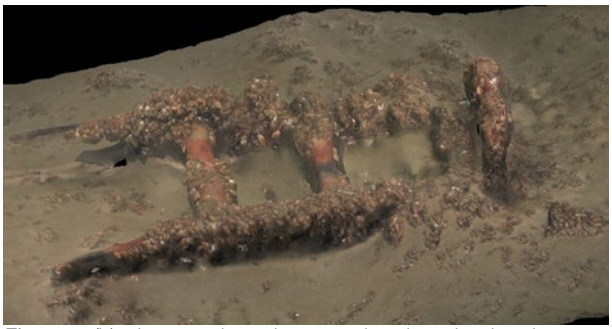


Figure 3-(b) photograph of the same hand truck taken in 2019. The two images taken nearly 40 years apart show the extreme sedimentation at the site. Whereas the hand truck was nearly fully exposed in 1980, it has been largely silted in since then. Additionally, the invasive species zebra mussels, which entered Lake Champlain in the 1990s, have colonized the site. Images courtesy of the LCMM.

The initial monitoring program focuses on two types of information: the biological activity in sediments surrounding the wreck; and observable changes like sediment deposition or visible degradation to the physical site. Sediment samples are being collected immediately adjacent to the wreck and at a location 25 m north of it to establish a baseline for the microbial communities living around the site. Future sampling will allow researchers to determine whether these communities change over time. Photogrammetric modelling of the wreck will create detailed three-dimensional models that can be compared from year to year to identify changes in the wreck and surrounding sediments. Future phases may include sampling the wooden hull itself to identify the wood species and monitor changes in its condition. These initiatives, along with the LCBP's annual monitoring of the lake's chemistry and collection of the lake's climatic variables, will allow for focused monitoring of all four concerning factors.

This work is intended to establish a practical, low-impact approach to monitoring freshwater shipwrecks over the long term. Rather than waiting until a wreck shows significant deterioration, regular environmental and archaeological observations can help identify changes early and improve our understanding of why they are occurring. The approach could eventually be expanded to other shipwrecks in Lake Champlain and to freshwater archaeological sites.

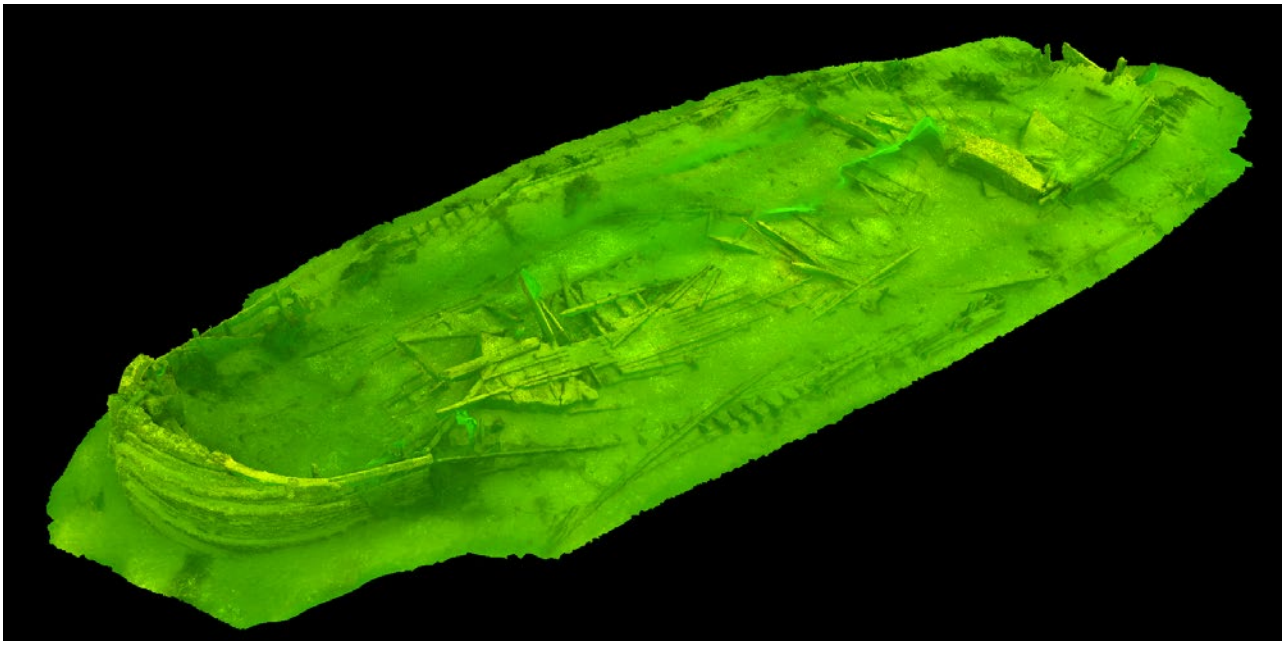


Figure 4- Pot Ash Point Canal Boat site. Image courtesy of the LCMM.

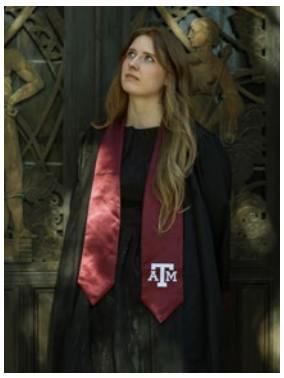
Ultimately, this project asks a simple question: if the environmental conditions that allowed historic shipwrecks to survive are changing, how can we recognize those changes early enough to protect them? By combining archaeological research with environmental science, we are developing practical ways to answer that question.



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At the Water's Edge: Climate Change and Coastal and Underwater Cultural Heritage in the Pacific

Ania M. Kotarba-Morley

Pacific communities have lived with the sea for millennia. Human occupation of Near Oceania extends back more than 40,000 years, while the settlement of Remote Oceania accelerated from around 3,300 years ago through successive episodes of long-distance maritime movement (Matisoo-Smith and Gosling 2025). These histories developed across coastlines that have never been static. At the Last Glacial Maximum, around 20,000 years ago, global sea level was approximately 120 m lower than today, exposing extensive areas of continental shelf, including the Sahul Shelf between Australia and New Guinea. Subsequent sea-level rise transformed those landscapes and provided an important deep-time context for considering the archaeological potential of the Pacific seabed.

Underwater cultural heritage (UCH) encompasses considerably more than shipwrecks. The 2001 UNESCO Convention defines it as traces of human existence of cultural, historical or archaeological character that have been partially or totally under water, periodically or continuously, for at least 100 years. It includes sites, structures, buildings, artefacts and human remains with their archaeological and natural contexts, as well as vessels, aircraft and their contents (UNESCO 2001). In the Pacific, this definition can encompass archaeological sites and cultural places, fish traps and other structures in intertidal and shallow-water environments, submerged landscapes and historic shipwrecks and aircraft. Recently inundated archaeological sites do not immediately become UCH under the Convention's 100-year definition, but their movement from terrestrial into intertidal and marine environments still requires archaeological management. The Pacific also contains an enormous legacy of World War II shipwrecks and aircraft which, although generally too recent to fall within the Convention's 100-year definition, may be protected through national legislation and other applicable legal regimes. Nevertheless, all of these sites are places of memory and, in many cases, human loss, while many have also become important recreational diving sites and contributors to local tourism economies, making their long-term preservation environmentally, culturally and economically significant.

Yet, climate change is altering the physical conditions in which this heritage survives. Rising sea levels and extreme coastal water levels expose shallow and intertidal sites to changing patterns of inundation and wave action, while changes in currents, storms and sediment movement can expose, erode or bury archaeological deposits. Ocean warming and changing seawater chemistry also affect marine environments and the physical, chemical and biological processes governing archaeological preservation. Gregory *et al*. (2022) show that the effects are complex and site-specific with environmental change accelerating deterioration in some settings, while sedimentation sometimes protects or conceals material in others. The Intergovernmental Panel on Climate Change (IPCC) identifies loss of cultural resources and heritage as one of eight interconnected key risks facing small islands, with their cumulative and cascading effects contributing to reduced island habitability (Mycoo *et al*. 2022).

A Remote Oceanic archipelago of Kiribati demonstrates the range of cultural material already present beneath Pacific waters. Oral histories and archaeological records identify submerged

traditional settlements, meeting places, burial sites and ancient fish weirs. At Temotu on Nonouti, divers have recorded coral pillars on the seabed arranged in the form of a traditional *maneaba* (meeting house). Submerged burial places are known at Bike on Abemama and Nei Teinaieta on Butaritari. Kiribati's UCH also includes nineteenth-century wrecks and extensive remains associated with the 1943 Battle of Tarawa World War II, particularly around Beito (Kotarba-Morley and Thomas 2020, Kotarba-Morley *et al*. 2024).

Elsewhere in the Pacific, the boundary between terrestrial, intertidal and underwater heritage is moving as coastlines change. This is important because the consequences and loss for archaeology and heritage begin before a site becomes permanently submerged with erosion removing stratigraphy, displacing artefacts and human remains, and destroying relationships between archaeological features and their landscape context. In such circumstances, once material enters a higher-energy intertidal or shallow-water environment, its preservation conditions may change substantially.

Kaurareg Country in southwestern Zenadth Kes (Torres Strait) illustrates such transition. On Muralag, ancestral burials, archaeological deposits and rock-art sites occur close to the present shoreline often in the dune systems (**Fig.1**). In 2021, climate change exacerbated coastal erosion during extreme king tides at Gaibayath exposed ancestral human remains within coastal dunes and the remains of a young woman were subsequently recovered and reburied (Kotarba-Morley *et al*. 2026). Other archaeological deposits on the island are also being eroded close to the shoreline (Kotarba-Morley *et al*. 2025), yet most of these places are not currently UCH under the Convention's definition. They are relevant though because they demonstrate how rapidly archaeological material and its context can move from a terrestrial preservation environment towards an intertidal and eventually marine one. Management systems that treat terrestrial and underwater archaeology as unrelated categories risk intervening only after much of that context has already been lost.

This problem is compounded by the limited knowledge of what lies underwater. Large areas of Pacific reef, lagoon, nearshore seabed and continental shelf have never been systematically surveyed for cultural heritage. Indigenous and local knowledge may identify cultural places that are absent from archaeological inventories, while earlier maritime surveys have often concentrated on readily identifiable wrecks. Climate-driven change can therefore affect sites whose extent, condition and sometimes existence have yet to be formally documented.

Establishing baseline information is one of therefore one of the most urgent responses. UNESCO places inventories at the centre of effective UCH protection, requiring competent authorities to establish, maintain and update inventories of underwater cultural heritage (UNESCO 2001). Such survey and monitoring can combine multibeam and sidescan sonar, photogrammetry, diver recording and other marine remote-sensing techniques with drones, LiDAR and satellite imagery in shallow and intertidal environments. Similarly, recording the surrounding environment is equally important as sediment cover, exposure, water depth, biological activity and evidence of movement help establish whether a site is stable and provide a baseline against which future change can be measured.

For Indigenous UCH, however, survey cannot begin and end with technology. Oral histories, place names, customary knowledge, fishing and navigation traditions and knowledge of former shorelines may identify the significance of features that remote sensing can only detect as physical anomalies. Communities also need authority over whether culturally sensitive places are surveyed, how information is recorded, who can access it and whether locations should be publicly mapped. Pacific UCH management therefore requires archaeological and marine science to work within Indigenous and customary governance rather than treating community knowledge as supplementary survey data.

This becomes particularly important as cultural heritage enters discussions of climate-related Loss and Damage. The *Reconnecting Oceania* White Paper identifies coastal erosion and inundation of sacred and culturally significant sites, including maritime archaeological heritage in the intertidal zone, as forms of cultural loss. Its recommendations call for stronger baselines and monitoring, community-led and Indigenous-led decision-making, cultural mapping, protection of cultural landscapes and seascapes, and



Figure 1- Aunty Enid Tom surveying Frenchman Cave with Kaurareg rock art which is currently at risk of erosion from sea level rise.

investment in archaeological sites and community archives to prevent both primary and secondary loss (Wairiu *et al*. 2026). The broader principle is to act before degradation becomes irreversible, rather than waiting until cultural systems or places have already been lost.

For UCH this has practical implications as climate finance and heritage funding can support inventories, condition assessments, community monitoring and repeated survey before sites reach critical thresholds. Where damage or destruction is imminent, high-resolution 3D recording, archaeological sampling and community-controlled documentation of associated histories and knowledges may retain information that would otherwise disappear. Such anticipatory documentation can reduce the loss of archaeological evidence, but—it is important to recognise that a digital record, although preventing secondary loss, is not a replacement for the cultural place itself.

Climate adaptation in the Pacific therefore needs to extend beneath the waterline. Underwater cultural heritage is already affected by changing physical, chemical and biological conditions, while archaeological sites presently on the coast are entering intertidal and marine environments. Effective management requires knowing what lies underwater, establishing baselines and how sites are changing, recognising key role of Indigenous knowledges, leadership and governance, and directing resources towards protecting and preserving (if only in record) sites at risk before archaeological context is irretrievably lost. Climate change may expose previously unknown heritage, but discovery through destruction is a poor substitute for preparedness.

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The Environment Institute at Adelaide University brings together researchers across disciplines to understand and respond to environmental and climate change. Its work connects people, nature and climate, generating—and translating—research that supports resilient ecosystems and communities. Adelaide University is Australia's new for-purpose university build from a merger of The University of Adelaide and University of South Australia, and focused on education, research and positive societal impact.



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Climate Change and Threats to Coastal and Underwater Cultural Heritage in New Zealand

Kurt Bennett, and *Matthew Campbell*

Introduction

New Zealand has one of the world's longest coastlines, its history intertwined with the sea. Polynesians arrived from the Pacific around 1250–1300 CE, Māori (indigenous peoples) settled the coast and Europeans arrived from 1769. Many of the country's most important heritage sites sit on beaches, in dunes, in estuaries and underwater, and include shell middens, shipwrecks and *waka* (canoes). Lying where land meets sea and below the waves, they are among the first places a changing climate reaches. This chapter describes how climate change threatens that heritage through four examples before offering solutions.

The threats

Seas are warming and rising and will keep rising for centuries. Storms are less clear-cut. Models do not agree they will become more frequent around New Zealand and their number is not projected to change robustly. However, the most intense storms, with their rainfall and winds, are projected to increase (IPCC, 2021; Gibson *et al*., 2025). Rising seas also raise the baseline for every surge, so impacts grow even without more storms. No single storm can be attributed to climate change alone, but it raises the likelihood and severity of the damaging ones.

The real problem is speed. Coastlines have always eroded, but faster now. Erosion that once took decades can happen in a single storm. Coastal archaeological sites are New Zealand's most common and the most exposed. About 12 per cent of recorded/known sites (over 9,000, more than half of them middens) lie in the coastal zone (Jones *et al*., 2023), and around 8 per cent of Northland's coastal sites are at risk from just 20 centimetres of sea-level rise, expected by about 2040 (Jones *et al*., 2024). Yet we cannot protect what has not been mapped.

Site examples

Midden, Ōmaro Spit, North Island

In February 2022, Cyclone Dovi stripped up to 40 metres of sand from the tip of Ōmaro Spit at the mouth of Whangapoua Harbour on the Coromandel Peninsula, exposing a midden half a metre deep (**Fig. 1**). In response, archaeologists recorded, sampled and analysed it. By 2025 a further 20 metres of the spit had gone and the midden with it (Campbell *et al*., 2025). Spits are naturally mobile, but rising seas and fiercer cyclones are tipping the balance towards permanent loss.



Figure 1- The midden after excavation at Ōmaro Spit (CFG Heritage).

In 2018, storm surges eroded a west-coast beach north of Auckland and uncovered *Daring*, a wooden trading schooner built in 1863 and wrecked in 1865. Buried for over 150 years, it is the best-preserved early-New Zealand-built ship. Once exposed it was washed by two tides a day and began to break apart (**Fig. 2**). A community group obtained consents and lifted the entire vessel off the beach. It is now conserved in Mangawhai, where it was originally built (Bennett *et al*., 2018). Such surges, on a higher sea, are projected to grow more damaging and impact beached sites like *Daring*.



Figure 2- The remains of Daring before recovery (Bennett).

baseline against which change can be measured (**Fig. 3**). A community-led project with the local museum trains divers to monitor it (Bennett *et al*., 2021).

At each site the trigger was a storm or ongoing erosion. These processes have always shaped these coasts but rising seas and fiercer storms make such losses more severe and less recoverable. Luck and goodwill cannot protect what cannot be replaced. Recording, rescue and monitoring each have a part to play.



Figure 3- A diver recording the HMS Buffalo timbers (HMS Buffalo Project).

Waka, Anaweka, South Island

On the north-west coast of South Island, the sea eroded the dunes near the Anaweka Estuary. In 2012, a family on a picnic spotted a large timber in the sand. It was part of an ocean-going canoe, carved from matai (a native wood) and dated to about 1350–1400 CE, one of the oldest directly dated canoes in Polynesia. Had it not been found, the sea would have taken it. The *waka* is now cared for as a *taonga* (treasure) (Johns *et al*., 2014). Dunes retreat naturally, but rising seas are accelerating that retreat, exposing what they once protected.

Shipwreck, HMS Buffalo, North Island

Not all coastal heritage sits on the shore. HMS *Buffalo*, a Royal Navy storeship wrecked in Mercury Bay on the Coromandel in 1840, now lies on the seabed. Submerged sites face the same pressures as storms shift sand to expose or bury timbers, and warmer, more acidic seas speed decay. With no plan to lift the wreck, the response is to monitor it *in situ*. Divers re-record it each year, building a

Solutions and best practice

The nation cannot save every site, but several steps can help:

- Record before loss. When a site cannot be saved, recording, measuring, sampling, photogrammetry, surveying, preserves the knowledge it holds, as at Ōmaro.
- Publish clear guidelines. Agreed national guidance on assessing, recording and protecting eroding coastal and underwater sites would help everyone act consistently. A key recommendation of the Ōmaro project recommended practitioners and regulators working together.
- Support communities and citizen science. Volunteers already do much of the monitoring. Repeat surveys of the Rainbow Warrior wreck through the GIRT Scientific Divers programme keep a long-term watch, even on sites outside the legal definition of an archaeological site. Funding is needed.

- Partner with iwi (tribes) and hapū (sub-tribes) as much of this heritage is Māori. Working together, and drawing on mātauranga Māori (Māori knowledge), guides better decisions.
- Map and prioritise. Knowing where sites are and which are most at risk allows action before the next storm. Tools like photogrammetry, GIS, GPR and GPS record sites quickly.

Conclusion

Climate change will keep reshaping the coastline, and some sites will be lost, but how much is partly our choice. By recording, publishing guidelines, backing and funding communities and iwi, monitoring what we can, and mapping what is most at risk, we can still save much and if not the sites themselves, then the knowledge they hold.



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Hidden heritage in a silent world - The potential impacts of climate change on historic underwater cultural heritage in Australia's Great Barrier Reef Marine Park

Andrew Viduka, and *Martin Gibbs*

Australia's World Heritage Listed Great Barrier Reef Marine Park (GBRMP) is recognised for its biodiversity and beauty. The park is managed for its natural, and strong ongoing Aboriginal and Torres Strait Islander values (UNESCO 2026). Inscribed in 1981, as the world's most extensive coral reef ecosystem, the GBRMP is globally outstanding, with the Park's boundaries covering an area of 348,000 square kilometres and extending across a contiguous latitudinal range of 14o (10oS to 24oS). The GBRMP includes some 3000 coral reefs, 600 continental islands, 300 coral cays, 150 inshore mangrove islands, as well as numerous Aboriginal and Torres Strait habitation sites, shell deposits (middens) and fish traps, together with historic period occupation, industrial and port sites (GBRMP Authority 2026). Many of these sites are exposed and could be adversely affected in most ordinary (SSP 2-24.5) and above climate scenarios.

Importantly, the threat of changing environmental conditions is not unique for Aboriginal and Torres Strait Islander people, but part of an evolving continuity in Sea Country connections over millennia, extending back beyond the formation of the modern form of the Great Barrier Reef (GBR) around 6000 - 9000 years ago (Great Barrier Reef Marine Park Authority 2026). For Sea Country, a term that recognises Aboriginal and Torres Strait Islander living heritage knowledge and connection in the coastal and marine environments, these climate scenarios pose a significant and real threat to current intangible cultural heritage customs and traditions. Environmental changes will impact habitat and the distribution and abundance of species, including totemic marine species. Sea level rise, higher seawater temperature, and more significant storm events will also peel away cultural relationships and traditional knowledge based on contemporary ecological understanding while physically impacting tangible sites such as fish traps, coastal middens and burial places (**Fig. 1**).

However, the Great Barrier Reef (GBR) also has a less well known and recognised heritage that has not met the thresholds, individually or collectively, for inclusion in National or World Heritage nominations, yet is both, a key part of the history of modern-



Figure 1- Fish trap on Goold Island, located in the central section of the GBRMP. Image courtesy of M.J. Rowland and S. Ulm. DERM ICHD Slide Collection.

day Australia and new in its vulnerability to climate change. Indeed, it was the exploration of the Barrier, to find safe passage for vessels through its intricate maze of reefs, narrow sandy passages, and shallow channels that made 'threading the needle' possible. This exploration made the GBR accessible to the majority of Australians and established our primary trade route to Asia for settlements on Australia's East Coast (Gibbs and McPhee 2004). Over 800 historic shipwrecks dating from 1770 to present, and tens of submerged aircraft are within the World Heritage listed boundary of the GBRMP (**Fig. 2**).

These underwater cultural heritage (UCH) sites include world famous wrecks such as HMS Pandora (1791) (**Fig. 3**) and SS *Yongala* (1911) (**Fig. 4**), but all the sites are significantly less well managed on a day-to-day basis than the GBRMP's Outstanding Universal Values due to the combination of lack of financial resources and prioritisation. However, their existence is the basis for unique assemblages of marine life even for the GBR (Malcolm *et al*., 1999) and form the critical basis for community identify (McIntyre-Tamwoy 2004), leisure (Pocock 2006) and for numerous blue economy activities throughout the GBRMP (Viduka and Raupp 2008).

In 2020, the Australian Government engaged the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to assess the vulnerability of Australia's World Heritage properties and to provide practical adaption planning for property managers (CSIRO 2022). The report, published in 2022, states clearly that 'over the past decade the risk of climate change has become a reality' (CSIRO 2022:



Figure 2- An image showing the location of the Great Barrier Reef in relation to Australia. Approximately 800 shipwrecks and tens of submerged aircraft are historically reported as lost inside the area highlighted green (image courtesy Wikimedia: Great Barrier Reef Marine Park Locator map. Creative Commons 4.0)



Figure 3- HMS Pandora (1791), located in the far northern section of the GBRMPA. While most of the site is buried, elements such as the cast iron Brodie stove, admiralty anchor and stern copper sheathing remain proud of the surface.

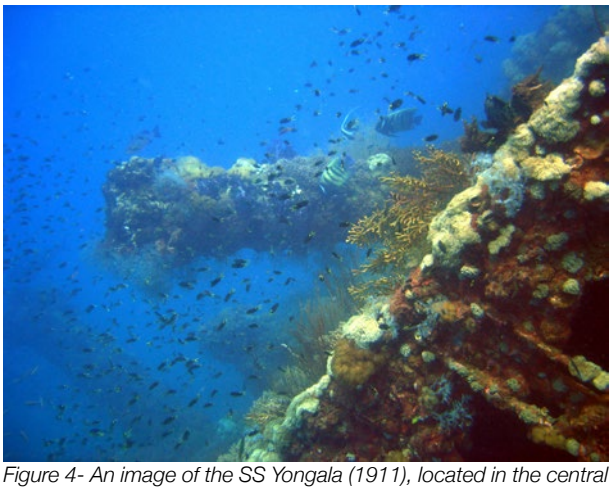


Figure 4- An image of the SS Yongala (1911), located in the central section of the GBRMP. The site is intact and sits proud of the seabed covered in coral with abundant marine life. Image Courtey of Yongala Express.

ix) and includes climate change risks, projected climate change and potential future climate change impact projections on listed values, based on the Intergovernmental Panel on Climate Change (IPCC) scenarios. Several of those projected impacts include a possible future from 2030 in which global average temperatures are 1.50 above pre-industrial conditions and where annual marine heatwaves are three times more likely (in line with SSP 1-2.6 Sustainability). Key climate change risks identified for the GBRMP are:

- 'Higher seawater temperature,
- Sea level rise and increased height of extreme sea level events,
- Ocean acidification
- More intense storms, cyclone activity and marine heatwaves
- Altered ocean currents
- Altered weather patterns (rainfall availability etc)' (CSIRO 2022: 41).

As stated in the 2024 GBRMP Outlook Report, 'Because historic shipwrecks are in a dynamic marine environment and likely to be subjected to accelerated natural degradation and human activities, the condition of these values is assumed to be declining' (GBRMP 2024). Unfortunately, the ability to report observed impacts on UCH in the GBRMP is problematic, not simply because of the size of the park and distribution and depth range of the UCH assemblage, quite simply, like many other places in the world, there is a '... lack of baseline data on underwater sites. Few have been surveyed at an appropriate level of detail, and even fewer monitored to provide repeat data that are suitable for change detection' (Gregory *et al*., 2022: 1406).

What we do know and what can be projected on UCH sites is that the physical, chemical, electro-chemical and biological deterioration processes that affect UCH, are being exacerbated by all the key climate change risks outlined above (Gregory *et al*., 2022; MacLeod and Viduka 2011). However, the "interrelatedness of everything" (Sesana *et al*., 2021: 10) influences deterioration processes, and some changes may improve preservation for some sites in certain micro-environments (Gregory *et al*. 2022: 1405). What is known is that the associated sessile life attached to wrecks and the fish and algae that swim or drift past the wrecks, will all be impacted in shallow waters, changing not only the aesthetic experience when diving sites, but threatening the structural integrity of shipwrecks sitting proud of the surface, such as *Yongala* (Fig. 4) and potentially even the micro-biological communities impacting UCH (Guthrie *et al*., 1994).

What needs to be done now to ensure this heritage is better protected in the future? As archaeology does not lend itself to transplanting/relocation without first excavation, an adaption plan for UCH in the GBRMP needs to be developed that considers all the UCH in the park, assesses each site's significance, archaeological potential and vulnerabilities, and establishes an ongoing monitoring program which can inform future management decisions. Least resilient are iron hulled shipwrecks sitting proud of the seabed, exposed to environmental changes and large weather events with limited mitigation

opportunities. Critically, due to the blue economy contribution of UCH in the GBRMP, there is the potential to improve our understanding of the complex ways environmental processes affect protected UCH beyond using existing human marine management resources, by giving the Australian diving community a critical role in monitoring UCH condition and site formation processes (Viduka 2020) (**Fig. 5**). In addition, and in line with the objectives of the Ocean Decade Heritage Network (ODHN 2019), further interdisciplinary engagement is required between UCH managers, marine scientists, other specialists, as well as the public. Lastly, and in parallel with these activities, and to enable the active interventive preservation of our historic UCH through excavation and or documentation, significant dedicated funding must be secured to ensure our UCH legacy is protected.

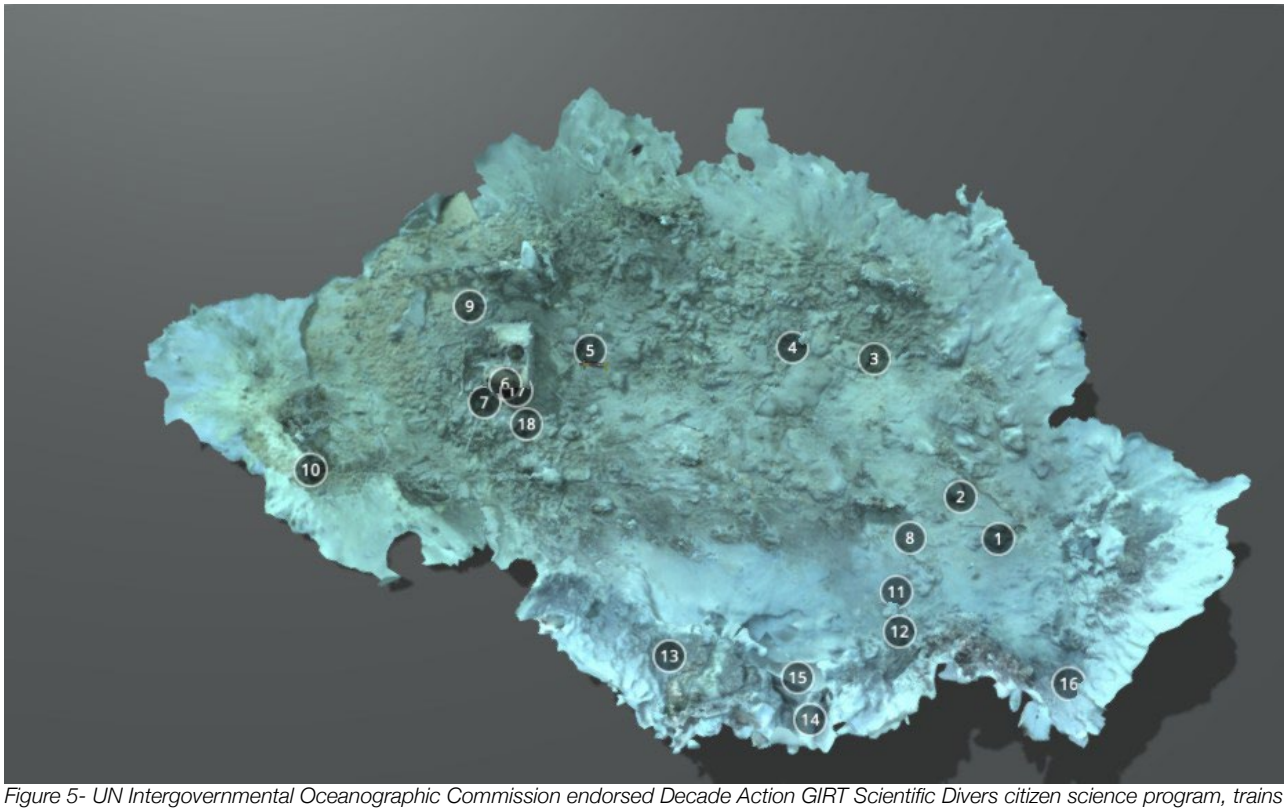


Figure 5- UN Intergovernmental Oceanographic Commission endorsed Decade Action GIRT Scientific Divers citizen science program, trains members of the public to systematically document observable physical and natural features of historic shipwrecks, submerged aircraft and other underwater cultural heritage in an open sea water environment, to facilitate their ongoing protection and management. Screen shot image of GIRT photogrammetry model of SS Gothenburg (1875), located in the central section of the GBRMP (https://skfb.ly/oAByP).

GIRT Scientific Divers

Gathering Information via Recreational and Technical (GIRT) Scientific Divers is a conservation focused no-impact citizen-science project. It aims to train members to systematically document observable physical and natural features of historic shipwrecks, submerged aircraft and other underwater cultural heritage in an open sea water environment, to facilitate their ongoing protection and management. GIRT aims to encourage interested people to have an active and positive public archaeology role. In late 2024, the UN Intergovernmental Oceanographic Commission endorsed GIRT Scientific Divers as Decade Action entitled "No. 56.6 GIRT Scientific Divers".



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Uncertain Future Of The Underwater Cultural Heritage Of Stone Tidal Weirs

Akifumi Iwabuchi

Stone Tidal Weirs

The underwater cultural heritage or living cultural heritage of stone tidal weirs is a type of fishing gear for sustainable or eco-friendly fisheries, made of numerous rocks, boulders, or reef limestones, which extends along the shoreline, sometimes on a colossal scale. Stone tidal weir shapes include semicircular, circular, quadrilateral, keyhole, arrowhead, or almost linear forms, of which the length sometimes reaches nearly one kilometer (**Fig. 1**). The passive fishing gear of stone tidal weirs is operated only by the strength of tidal amplitude. At high tide, it is completely submerged beneath the sea, while at low tide, particularly during the spring tide, it reveals its entire structure on the tidal zone. Then, fishermen step into such weirs in order to catch fish that fail to escape from them due to the stone walls, either by hand or with small fishing tools such as hand nets or fishing spears shaped like tridents. In Timor, only fish spears are allowed to be used inside stone tidal weirs to prevent overfishing: as they function not only as fishing gear but also as fish spawning grounds. In South Africa, the artificial stone tidal weir can also serve as a novel and important habitat for a wide range of planktonic marine organisms, including fish and invertebrate larvae, since they are completely submerged during high tide, retaining water in an enclosed pool with the outgoing ebb tide (Pattrick *et al*., 2022, p. 3). In North America, too, the very building of a clam garden wall, or any intertidal or subtidal rock feature, creates habitats for a variety of valued species, such as sea cucumbers, crabs, and small fish (Lepofsky *et al*., 2013, p. 7), which have brought rich biodiversity to the sea.

Under Climate Change

The coastal and underwater cultural heritage along the intertidal zones is extremely vulnerable to ocean climate change, specifically to global sea level rise. In the South Pacific, some of the coastal graveyards have been washed away, and there was one occasion when a coffin started to float to the surface due to the high tide before it was buried (Veitayaki, 2007, p. 3). The stone tidal weirs, no less than such coastal graves, are in a dangerous situation. If sea levels rise more than a metre, stone tidal weirs operated only by tide range no longer function as fishing gear. In recent years, high waves have been gradually eroding the stone walls. As a result, the walls have become lower to begin with, making them even more vulnerable to rising sea levels.

In Kohama Island of the Ryukyu Archipelago, the average height of the stone walls of the largest tidal weir is 0.6 metres. In the 1970s, the average water depth at high tide during the spring tide was 2.3 metres, and that during the neap tide was 1 metre (Yano *et al*., 2002, pp. 57-64). Around this area, the tidal range is approximately 1 metre, and the average elevation of sea level has been more than 0.1 metres over the last 50 years, while the rate of rise now approaches 0.0035 metres per year (Okinawa Meteorological Observatory, 2026). Because each wall of stone tidal weirs on the Jingweicun Peninsula of China is as much as 2 to 3 metres high, they will not be submerged even though the global mean sea level rises by 0.77 metres by 2100 (Guo *et al*., 2023 p. 7). The highest wall of a stone tidal weir in Hainan Island is over 6 metres high (Wang, 2025, p. 62), so it is expected to remain unaffected by sea level rise for



Figure 1- Timorese Stone Tidal Weirs. © Akifumi Iwabuchi.

the foreseeable future. However, a model study that evaluates potential risks to various types of cultural heritage along China's coastal areas, suggests that villages and their cultural heritage items along the northern coast of Hainan Island are potentially at high risk due to sea level rise, being extremely vulnerable (Chen *et al*., 2024, pp. 7-10).

Increasing wave strength and size, and strong winds caused by typhoons and cyclones, or sometimes earthquakes have historically destroyed stone tidal weirs (**Fig. 2**). In particular, southern China, Formosa (modern day Taiwan), the Ryukyu Archipelago, southern Japan, and the Philippines, all of which have stone tidal weirs, and are hit by large-scale typhoons almost every year. Most of the stone tidal weirs along the northern coast of Miyako Island in the Ryukyu Archipelago were wiped out by a powerful typhoon in 1959 and by a tsunami caused by the 1960 Valdivia earthquake (Nishimura, 1981, p. 257). In the Penghu Islands in the Taiwan Strait, the decline of stone tidal weirs seems to be attributed to typhoons and climate change, which have caused rising sea temperatures and environmental pollution. This has resulted in the death of coral reefs and the accumulation of coral reef debris in the stone weirs, reducing their capacity to serve as a wildlife habitat. Eventually, this has led to a declining fish populations in these areas (Lee *et al*., 2026, p. 236). A stone tidal weir in the Philippines' Panay Island was owned by a man. As long as he lived, his nephew helped him repair the stone wall, which was susceptible to crumbling whenever strong waves hit it. After his death in 1993, however, no one has maintained the stone tidal weir, which is now in ruins (Zayas, 2011, p. 74). If even a part of the stone walls is destroyed, the stone tidal weir itself becomes useless. Repairing the stone walls requires a significant amount of time and manpower. In East Asia, the rapid intensity of typhoons, due to global ocean warming and changes in atmospheric temperature and humidity, has recently exhibited a strengthening trend (Wang *et al*., 2024, p. 3718).

The decline of stone tidal weirs is not solely due to global climate change. The main reason stone tidal weirs have fallen out of use in the last century, particularly in industrialized countries, is the spread of commercial fishing fleets and rapid coastal development. The disappearance of stone tidal weirs proceeds along the lines as follows. First of all, there is a decrease in the community's interest in stone tidal weirs, because they do not manage to catch many fish anymore, due to the effects of rising sea levels and other factors such as environmental



Figure 2- Destroyed Stone Tidal Weirs in Japan. © Akifumi Iwabuchi.

pollution including the increasing amounts of marine debris. Secondly, rituals or ceremonies surrounding stone tidal weirs are slowly falling into decline. After stone tidal weirs are destroyed by destructive wave actions, thirdly, the coastal community cannot afford to prioritize enough manpower to repair or reconstruct them (**Fig. 3**). Finally, the intangible cultural heritage of traditional ecological knowledge or cosmology associated with stone tidal weirs fades into oblivion. In South America, to put it simply, many stone tidal weirs went from being everyday elements of communal life to being virtually unknown to recent generations due to the aging population and the shrinking population in the region (Álvarez *et al*., 2019, p. 164).

Uncertain Future

The underwater cultural heritage of stone tidal weirs globally faces threats from sea level rise, destructive storms, or ocean acidification caused by climate change. However, the decline in the number of stone tidal weirs worldwide had already started long before climate change began in earnest, but it is also now possible to interpret that climate change is accelerating this phenomenon. Ten years from now, it is likely that in many places, no one will be using stone tidal weirs as active fishing gear. Relocating stone tidal weirs to museums is completely out of the question. Even when the intangible aspects are lost and it is no longer in use, the underwater cultural heritage of stone tidal weirs will, indeed, continue to be part of the seascape and will remain an archaeological site that bears witness to its past use. However, it is no longer a living cultural heritage, and it is not so easy for dissolving coastal communities to safeguard only its tangible aspects. Although some local conservation groups, which have so far been established for only a small number of weirs, and the 2001 UNESCO *Convention on the Protection*



Figure 3- Abandoned Stone Tidal Weirs in China. © Akifumi Iwabuchi.

of the Underwater Cultural Heritage are, to some extent, beneficial for extending the lives of stone tidal weirs, they are practically powerless against modern acculturation and global climate change.

The response from most governmental sectors responsible for underwater cultural heritage has also been slow because stone tidal weirs are not shipwrecks.

TUMSAT is a national university in Japan that conducts basic and applied education and research in marine-related science and technology to advance it for humanity. It also leads another project of the UN Decade of Ocean Science for Sustainable Development (2021-2030) titled 'Aquaculture Industry and Marine Literacy Education Promotion Project'.



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Climate Change Risks to Macao's Coastal Cultural Heritage

Zhehao Zhao

Macao is a coastal heritage city located on the western side of the Pearl River Estuary. Its development was closely associated with maritime trade, missionary activity, port functions, and transoceanic exchange. Extensive land reclamation since the nineteenth century has transformed the historical coastline, harbour configuration, and urban morphology, changing the relationship between heritage assets and the sea (ICM, 2019; Teng *et al*., 2021; Lei, 2024). Today, sea-level rise, storm surges, typhoons, flooding, and long-term environmental change pose increasing challenges to the city's cultural heritage (Wang *et al*., 2016; Long and Gao, 2023).

Climate Change Hazards and Risks

Macao's historic urban landscape is situated within a highly modified coastal environment. Successive land reclamation projects since the nineteenth century have transformed former shorelines, harbour approaches, and waterfront spaces into urban districts, fundamentally altering the relationship between the city and the sea. At the same time, these changes have increased the complexity of climate-related risks facing the Historic Centre of Macao and other heritage locations.

Sea-level rise represents one of the most significant long-term challenges. Modelling studies suggest that rising sea levels may increase flooding, drainage-system backflow, and storm-surge impacts across low-lying parts of the territory (Wang *et al*., 2016; Long and Gao, 2023). In addition, reclamation has altered coastal water conditions and environmental processes, creating new forms of interaction between urban development and the marine environment (Zhang *et al*., 2024).

Long-term climatic change may also accelerate material deterioration. Macao's mean surface air temperature increased by approximately 0.71°C between 1901 and 2007 (Fong *et al*., 2010). Increasing temperatures, humidity, saline moisture, and biological growth place additional pressure on historic materials and contribute to the gradual weathering of heritage structures.

A notable example occurred in June 2024 when stone fragments were discovered at the base of the Ruins of St. Paul's during severe thunderstorms. Subsequent inspections identified no major structural instability, but the incident highlighted the vulnerability of exposed historic masonry to increasingly unpredictable weather conditions (ICM, 2024).

Typhoons remain the most visible climate hazard affecting Macao's cultural heritage. The most severe recent example was Typhoon Hato (2017). Post-disaster inspections documented damage to portions of the perimeter walls of Guia Fortress, collapse of its historic typhoon signal mast, failure of part of the porch ceiling at Dom Pedro V Theatre, and deformation of maintenance scaffolding at St. Joseph's Seminary (ICM, 2017).

Additional impacts were observed following Typhoon Mangkhut (2018), including broken windows, plaster deterioration, seepage, and minor roof damage affecting several historic buildings, temples, and churches (ICM, 2018). Similar conditions were reported after Super Typhoon Huajiasha (2025), when inspections recorded

loosened wooden windows at Guia Fortress, fallen branches at St. Joseph's Seminary, and localized seepage and water accumulation at St. Augustine's Church and St. Lawrence's Church (Macao SAR Government, 2025c).

Flooding represents one of the most disruptive climate-related consequences for heritage cities because its impacts often extend beyond building damage. Recent events illustrate the extent of flood-related vulnerability across Macao's historic urban landscape. During the Black Rainstorm event associated with the outer rainbands of Tropical Cyclone Yangliu in August 2025, widespread flooding and drainage-system overload were reported across the territory, including areas surrounding the Yilong Firecracker Factory heritage landscape (Jornal San Wa Ou, 2025). Similar conditions were observed during Super Typhoon Huajiasha in September 2025, when flooding affected Largo do Presidente António Ramalho Eanes, Rua de Cinco de Outubro, and Rua dos Barqueiros in Coloane (Macao Daily, 2025).

The principal consequence of flooding is not always structural collapse but is the temporary loss of accessibility and functionality. Historic streets, public squares, and culturally significant urban spaces may remain physically intact while becoming difficult to access or use. Flood events therefore affect not only heritage buildings but also the wider historic urban environments through which heritage is experienced and interpreted (**Fig 1**).

Taken together, these hazards demonstrate that climate change threatens Macao's coastal cultural heritage through multiple pathways. Some impacts are expressed through direct damage to historic structures, while others emerge through environmental deterioration, flooding, and disruption of the historic urban landscape.

Adaptation and Resilience

As climate-related impacts are already affecting heritage assets through typhoon damage, flooding, moisture ingress, material deterioration, and other environmental stresses. Effective adaptation therefore requires a shift from reactive post-disaster intervention towards preventive and resilience-oriented conservation. A substantial foundation for this transition already exists. The Protection and



Figure 1- Flooding within Macao's historic center following Typhoon Hato (2017).

Management Plan for the Historic Centre of Macao established a framework for conservation, heritage impact assessment, risk management, and streetscape protection (Macao SAR Government, 2024). The Macao World Heritage Monitoring Centre has further strengthened the capacity for continuous monitoring and early detection of change through technology-based observation systems (ICM, 2022).

Preventive conservation should remain the first pillar of adaptation. Existing measures include pre-typhoon inspections of vulnerable heritage sites (Macao SAR Government, 2025a) post-event condition assessments (Macao SAR Government, 2025c), and technical evaluations of building components most susceptible to wind and rain damage, such as roofs, timber elements, and suspended ceilings (ICM, 2016). Recent conservation projects have increasingly focused on addressing moisture ingress, salt-related deterioration, and other climate-sensitive forms of material decay affecting historic structures (**Fig. 2**). Digital technologies provide a second avenue for adaptation. Continuous monitoring systems already support the observation of heritage



Figure 2- Salt-crystallisation treatment at the Former Chinese and Western Pharmacy Site.

conditions (ICM, 2022). Expanding the use of drone surveys, three-dimensional documentation, digital inventories, and environmental monitoring would improve risk assessment and support evidence-based conservation.

Adaptation must also address heritage settings and cultural landscapes rather than focusing solely on individual monuments. Extreme weather events frequently affect public spaces, waterfront environments, vegetation, drainage systems, and access routes, even when heritage structures remain intact. Projects such as the Inner Harbour Tidal Barrier Project (DSAMA, 2025) and the Coloane Western Flood Prevention Project (Macao SAR Government, 2025b) already recognise the need for resilience at the landscape scale. Future adaptation should therefore integrate heritage conservation with flood management, landscape maintenance, and public-space planning.

Community responses contribute to resilience. Flood-level markings recorded by residents on building facades provide a local example of climate memory and informal adaptation. By preserving records of previous inundation events within the urban landscape, these markings support awareness of recurring flood risk and help transmit local knowledge across generations (**Fig. 3)**.

Finally, adaptation priorities should reflect cultural significance as well as physical exposure. Existing frameworks, including the Ten-Year Plan for Disaster Prevention and Mitigation (2019–2028) (Macao SAR Government, 2019) and the Civil Protection Legal System (Macao SAR Government, 2020), provide an important basis for risk reduction. From this perspective, A-Ma Temple, Guia Fortress, and other highly significant maritime heritage sites warrant particular attention because climate-related impacts affecting these places may generate disproportionately large cultural consequences for Macao's heritage system.

Climate change poses growing challenges to Macao's coastal cultural heritage through sea-level rise, typhoons, flooding, and long-term environmental stress. Recent events demonstrate that risks extend beyond individual monuments to affect wider historic environments and cultural landscapes. Strengthening resilience therefore requires a combination of preventive conservation, environmental monitoring, flood management, and integrated heritage planning. As climate pressures intensify, safeguarding Macao's distinctive coastal heritage will depend increasingly on the ability to adapt historic places and cultural landscapes to changing environmental conditions.



Figure 3- Community-recorded flood marks in Macao.



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Managing Decay on an Ice-Bound Frontier: Potential Climate Change Impacts on the Underwater Cultural Heritage of Heard Island

Dragomir Garbov and *Liam Norris*

The Australian External Territory of Heard Island and the McDonald Islands (HIMI) is among the world's most remote island groups (**Fig.1**). Located in the Southern Indian Ocean, some 1720 km north of Antarctica, the UNESCO World Heritage Property and Marine Reserve preserves potentially significant, but poorly understood underwater cultural heritage (UCH) associated with nineteenth-century elephant sealing. A recent investigation has identified substantial archival evidence for eight historic shipwreck events associated with the First Elephanting Period of HIMI's history (1855-1882) and two unidentified wooden wrecks reported on shore at Heard Island in 1856 and 1949, as well as evidence for lost ground tackle, small craft, and ritual seabed deposits reflecting the New England whaling practice of "heaving" the tryworks overboard at the end of a successful season (Garbov & Norris 2026). Heard Island's UCH potential extends from the intertidal zone to approximately 45 m depth,

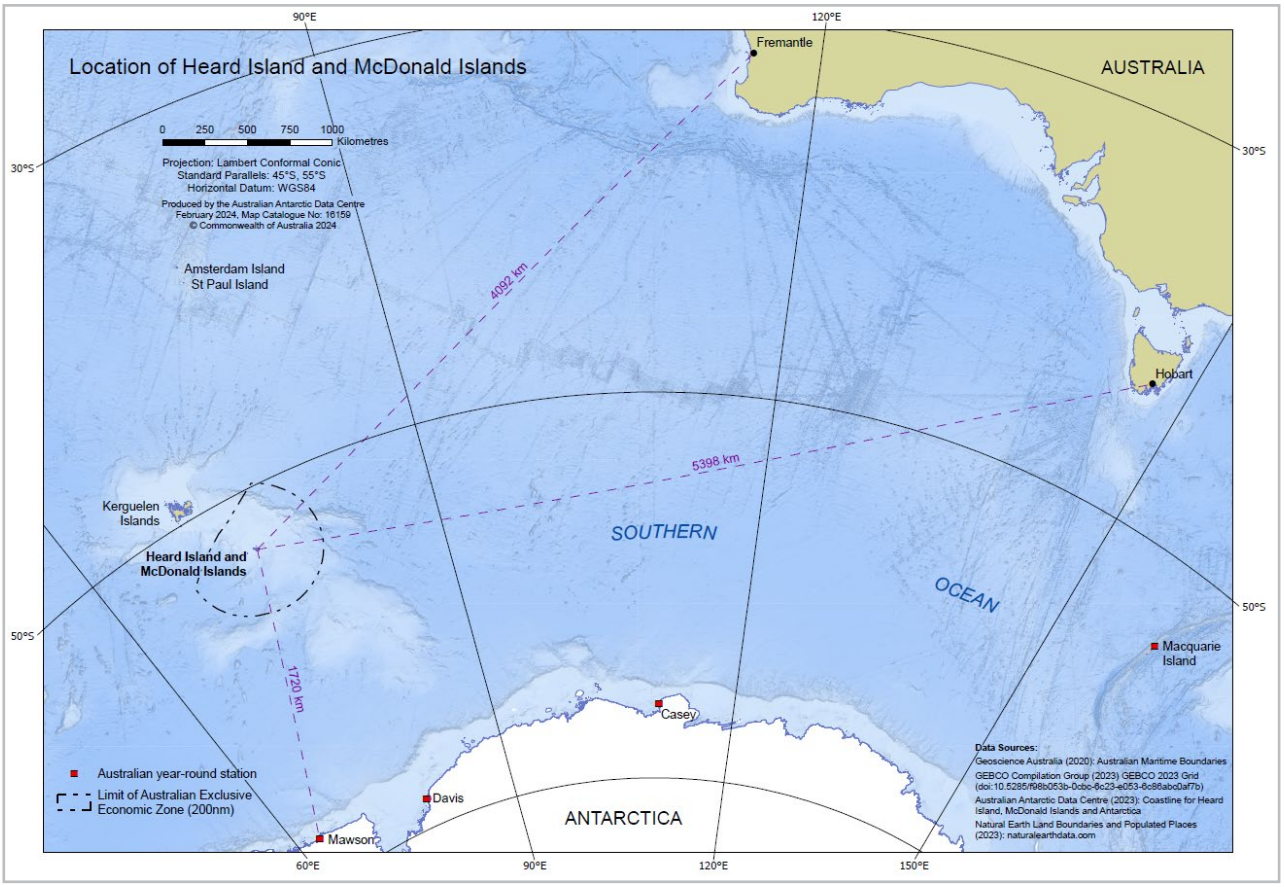


Figure 1- Location of Heat Island and McDonald Islands in the Southern Indian Ocean (Australian Antarctic Division, Map 16159, February 2024).

encompassing beaches, historic anchorages and submerged environments (**Fig. 2**). While the island has been found to be undergoing substantial and accelerating climate-related environmental change (Thost and Truffer 2008; Schmieder 2023; Tielidze *et al.* 2025), most of its UCH has never been physically located or archaeologically assessed.

Baseline information is critical for UCH management and increasingly important in the context of climate change. The 2021 Australian state of the environment report for Antarctica identified that rapid glacial retreat has transformed parts of the island through the conversion of ice cliffs and glaciers to lagoons, pro-glacial lakes and newly exposed terrain (Wienecke, Klekociuk and Welsford 2021). The 2022 assessment of climate vulnerability of Australian World Heritage properties identified rising sea-surface temperatures, strengthening westerly winds, more intense storms, deglaciation, sea-level rise, increased rainfall and changing ocean chemistry as principal climate risks for HIMI, where sea-surface temperature is projected to increase by approximately 1–1.5°C by 2040, atmospheric temperature by 0.5–1°C by 2050 and sea level by approximately 0.1–0.2 m by mid-century (CSIRO *et al*. 2022).

In UCH the management of climate change is rarely understood as a singular process with a predictable deterioration outcome. According to Gregory *et al*. (2022), such impacts result from complex interactions between physical, chemical and biological processes influenced by anthropogenic activity. These interactions make it difficult to isolate a discrete climate-change "signal" from the standard processes of site formation and deterioration. Furthermore, changes that accelerate degradation in one archaeological microenvironment may have different, or even temporarily beneficial, effects in another.

At Heard Island, the most immediate climate change impacts to UCH would be associated with alterations of the coastal zone. Increasing temperatures, sea-level rise, stronger storms and changing wave regimes may increase erosion and modify shorelines, affecting potential archaeology buried in beaches or within shallow and intertidal environments. A key aspect of modification along the island's eastern coast is associated with its most notable features, namely a series of glaciers which historically terminated in coastal ice cliffs (**Fig. 3**).

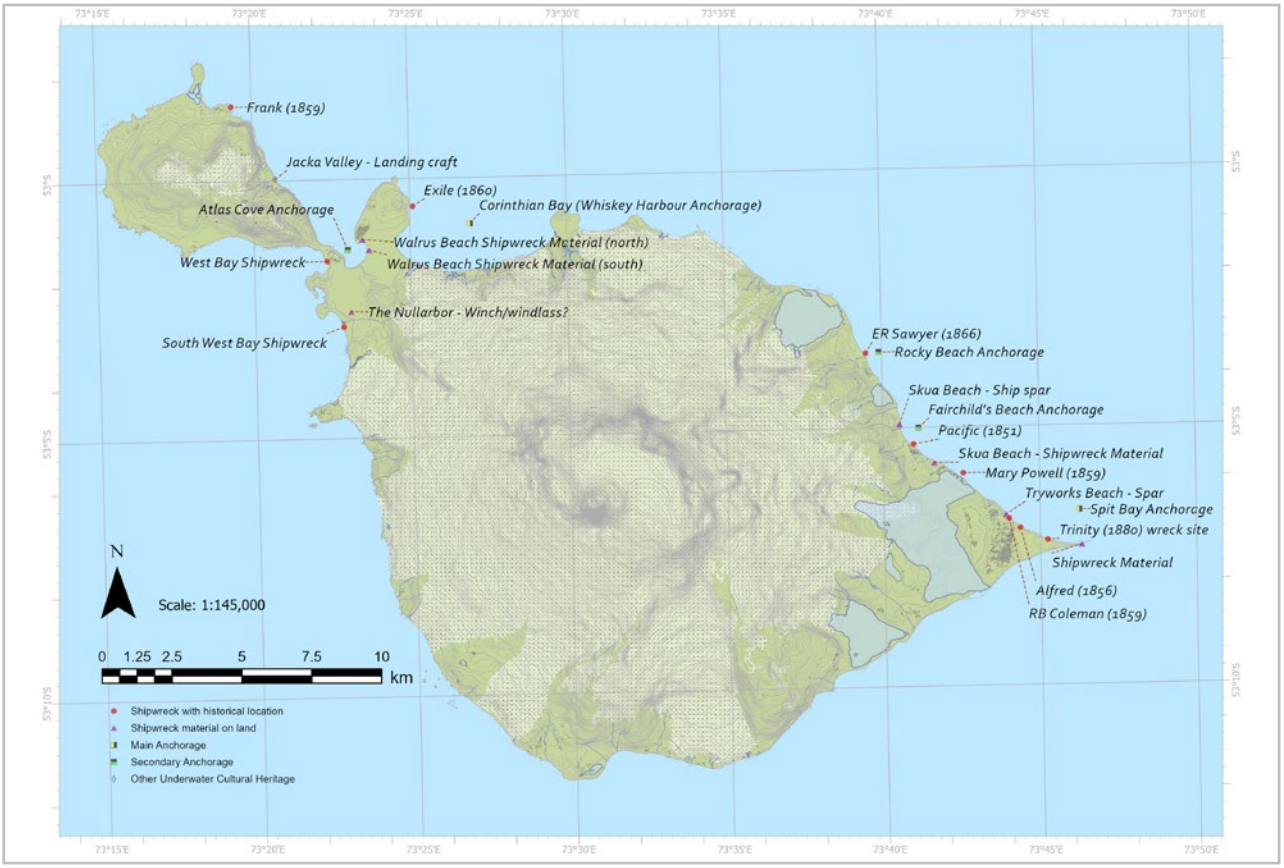


Figure 2- General distribution of UCH (identified and potential items) at Heard Island (produced by the Australian Antarctic Data Centre, March 2025; map available at: data.aad.gov.au © Commonwealth of Australia 2025).



Figure 3- Ice cliffs and beach scape on Heard Island (photograph by Kerry Steinberner, Australian Antarctic Division, 2008).

The 1859 wreck of 240-ton two-masted whaling schooner *Mary Powell* demonstrates the relationship between this landscape and archaeological potential. The vessel was lost after a collision with the ice-cliff face of Stephenson Glacier. It was abandoned by the crew, with the captain (Nash) taken aboard another Connecticut schooner named *Pacific* (Capt. Boles; **Fig. 4**).

A contemporary account documents a key episode in the site's formation history:

> *"A rather curious incident occurred as Capt Boles was leaving that part of the coast where the people lived, and had reached the up and down cliffs where the wreck of the Mary Powell was yet above water. Capt Boles called Capt Nash up out of the cabin to see the last of his schooner. Capt Nash came up, and he was leaning over the side having a parting glance and thinking no doubt of old times in his fine schooner. Suddenly a great fall of ice fell on the shipwreck, covering up the whole ship. Capt Nash was very much affected by this incident and went below to his cabin."* (Hobart Town Mercury, 13 Jan. 1860).

Stephenson Glacier has subsequently undergone substantial modifications, where the ice cliffs have melted and are now a coastal lagoon (Donoghue 2021). This significantly complicates the reconstruction of the vessel's original wrecking environment and the likely location and condition of her surviving remains.

Changing hydrodynamic conditions may also affect submerged sites. Shipwrecks and submerged archaeological deposits are vulnerable to changes in sediment transport. Increased scour may expose previously buried material, while altered sedimentation may bury or redistribute material. Such changes are impossible to assess where archaeological sites lack basic geophysical and/or monitoring data against which seabed change can be measured (Gregory *et al*. 2022). At Heard Island this problem is acute: the locations and condition of all historic shipwrecks remain inferred from archival sources.

Climate-driven changes to seawater may affect material preservation. Sesana *et al*. (2021) identify

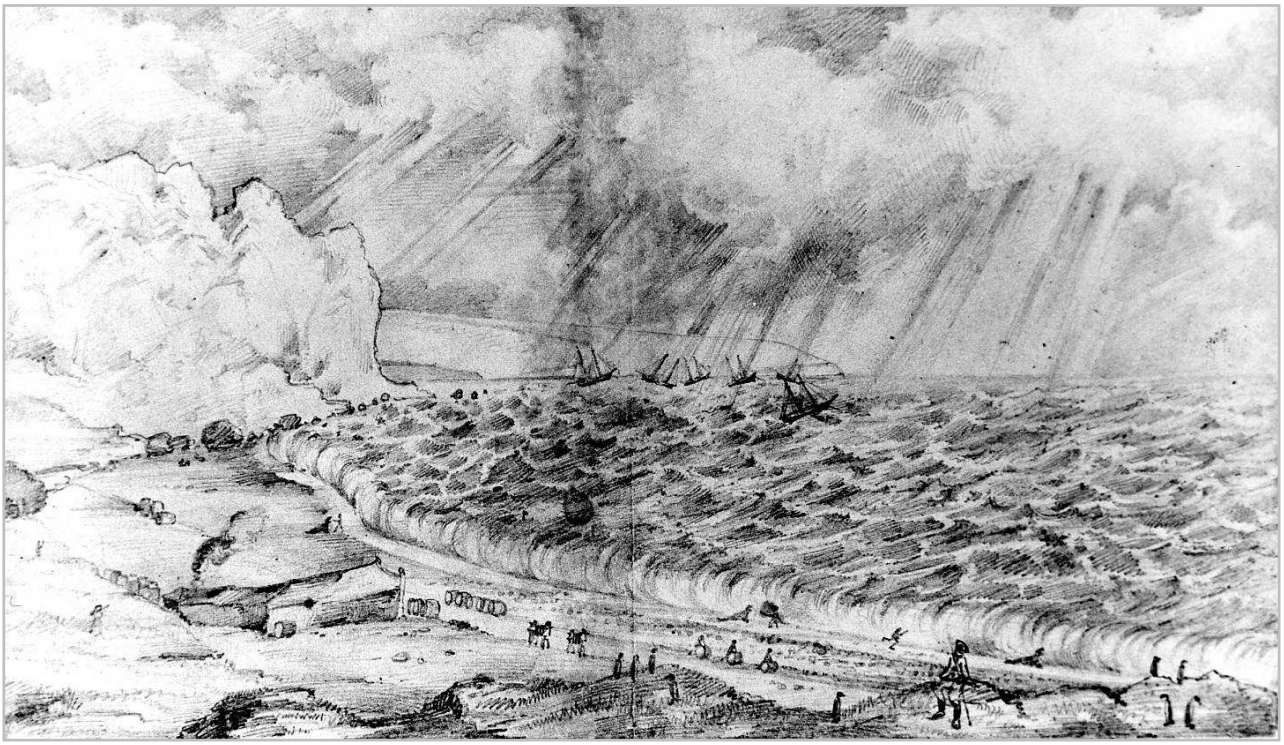


Figure 4- "View of Heard Island with the schooner Eliza Jane dragging her anchors" (pencil sketch by W. T. Peters, New London County Historical Society, after Downes 2002, Fizgure 14). The drawing shows the Landing (the north beach at Spit Bay) with Stephenson Glacier during the peak season of 1858-59.

changes in sea temperature, currents, oxygen levels and salinity as potential influences on shipwrecks and submerged archaeological sites, while ocean acidification may affect corrosion processes associated with iron and steel. The preservation of individual sites in waters off Heard Island will therefore depend on composition, sedimentary context, exposure and local biochemical conditions. The 2026 Garbov and Norris assessment identified that while *Teredo navalis* has not yet been documented, preservation may vary substantially between wholly buried, intermittently exposed, intertidal and fully exposed archaeological material.

In summary, in the case of Heard Island, the principal problem of managing and adapting to climate change is uncertainty. Unlike climate effects on some terrestrial components of the island's heritage, presently climate-related deterioration of UCH cannot be measured because there is no condition baseline. This reflects a broader problem for UCH internationally: relatively few sites have been recorded at sufficient resolution (none in the Antarctic and Sub-Antarctic, other than Shackleton's Endurance; see other contribution of Garbov in the current volume), and fewer still are monitored regularly to allow environmental change to be quantified (Gregory *et al*. 2022).

The problem is pertinent at Heard Island, where extreme remoteness and infrequency of access have resulted in a policy of 'managed decay' for its significant terrestrial cultural heritage (Wienecke, Klekociuk and Welsford 2021; **Fig. 5**). While 'managing to ruin' is an acceptable approach for UCH, climate change potentially complicates things as managed decay assumes some understanding of the processes and trajectories through which heritage is deteriorating; for the island's UCH, however, neither its baseline condition nor rate of change has been established.

Climate adaptation for Heard Island UCH should therefore begin with establishing that baseline. The first step has been made with the Garbov and Norris assessment, which provided an inventory of potential UCH items on and in waters off Heard Island incorporating the relevant information in the Australasian UCH Database, Australia's national register of protected UCH. Further steps should comprise on-site works to establish the presence/absence, nature and extent of actual UCH sites as preserved on the island as an initial condition baseline.

Climate-driven alteration of the island's eastern coastline, where most potential UCH sites are



Figure 5- Seal oil casks left by the castaways of the American barque Trinity, 1882, photographed by Australian Antarctic Division expeditioners 103 years later (photograph by Robert (Bob) Jones, Australian Antarctic Division, 1985). The 2021 state of the environment report established that some of them are still present.

expected, is a specific factor requiring consideration. Accelerating coastal modification is increasing the urgency of locating and assessing the potential archaeological resource. Future hydrographic and environmental campaigns provide opportunities for UCH surveys using side-scan sonar, multibeam bathymetry, sub-bottom profiling and magnetometry to identify archaeological anomalies. These can be supplemented by LiDAR (Light Detection and Ranging) and aerial photogrammetry in shallow and intertidal environments. Targeted ROV (Remotely Operated Vehicle) or archaeological-diver inspection can then establish site identity, condition, burial state and vulnerability. Only then can adequate climate change adaptation and management measures be designed and built into future management protocols.

The potential climate-change impacts on Heard Island UCH extend beyond the basic prospect of accelerated deterioration. Climate change is modifying the coastal and marine environments within which archaeological sites survive and, in some cases, the historic landscapes required to locate and interpret them. Heard Island demonstrates a fundamental challenge for climate adaptation in UCH management: already vulnerable heritage items may be disappearing before basic ideas on their extent and condition have been formed. Locating, characterising and monitoring representative sites is therefore necessary not simply for their protection, but for distinguishing climate-driven change from standard archaeological site-formation process and for developing proportionate, evidence-based adaptive management.

Institute of Nautical Archaeology

The Institute of Nautical Archaeology (INA) is committed to locating, excavating, recording, preserving, and publishing shipwrecks and other archaeological sites of maritime significance all over the world. INA is a non-profit, international research organization founded in 1972 by Dr. George F. Bass †, who pioneered the science of archaeological excavation under water.



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In 2026, he led the preparation of the first underwater cultural heritage assessment of the Heard Island and McDonald Islands. He also holds a range of recreational and commercial diving qualifications, supporting his extensive fieldwork in maritime and underwater archaeology.

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Climate Change Risks to Coastal and Underwater Cultural Heritage in Pakistan

Amer Bazl Khan

Pakistan's coastline within Sindh and Balochistan encompasses a diverse maritime cultural heritage comprising archaeological ports and settlements, fortifications, lighthouses, sacred places, historic shipwrecks, submerged archaeological sites and cultural landscapes linked to generations of maritime communities (**Fig. 1**). Climate change threatens this cultural heritage, while also undermining the traditional relationships through which coastal communities engage with the sea.



Figure 1- Coastal flooding around the historical 5th century site of Ratukot in the Indus Delta (courtesy MaritimEA 2024.)

Following the Intergovernmental Panel on Climate Change (IPCC) framework, climate risk represents the combination of climate-related hazards, exposure and vulnerability (IPCC 2022). This becomes particularly important for the communities along the coast of Pakistan, where the influences of climate change exist against a backdrop of other processes and drivers. Coastal development, reduced freshwater and sediment delivery to the Indus Delta, pollution and changing land use all interact with climate-related hazards to produce compound and cascading risks.

Climate-related hazards and risks

Sea-level rise, coastal inundation and erosion are amongst the major long-term risks, particularly within the low-lying Indus Delta. Recent modelling by Mitra *et al*. (2024), estimates potential inundation from 307.36 km² to as much as 7,150.8 km². Using the study's mean sea-level-rise projections, by 2150 the delta is projected to lose over 550 km² of agricultural land and approximately 535 km² of mangrove cover.

The changes observed in the shoreline are already illustrating the vulnerabilities of the delta. Analysis of satellite imagery for 1972-2017 by Siyal *et al*. (2022) found that erosion predominated over accretion, with a mean net erosion rate of 18.87 ± 2.22 m per year. More recent analysis of 1990-2020 satellite data (Batool *et al*. 2025) identified overall shoreline retreat, reporting a mean net shoreline movement of approximately -1,810 m.

Such changes will have direct implications for coastal heritage. Archaeological sites along creeks, tidal channels and low-lying coastlines could be increasingly exposed to coastal erosion and tidal inundation. Within the Indus Delta, historical port cities such as *Banbhore*, *Lahiri Bandar*, *Ratukot* and *Jam Jaskar Goth* demonstrate how historical landscapes are rapidly changing within riverine, intertidal and coastal environments. It is also important that shoreline retreat can be attributed to other drivers than climate change. Reduced downstream delivery of freshwater and sediment resulting from dams, barrages and irrigation systems has compromised the ability of the delta to maintain its coastline. (Abbas *et al* 2018). Climate-related sea-level rise thus acts upon an incredibly modified and sediment stressed deltaic system. Tropical cyclones, storm surges, extreme precipitation and flooding are further hazards. Such events can cause erosion, sediment redistribution, waterlogging and salt contamination (Gregory *et al* 2022). Within the context of disaster response, such hazards can also result in cascading secondary impacts i.e. loss of infrastructure, necessary re-allocation of government resources towards urgent humanitarian priorities, and displaced communities, leaving archaeological sites vulnerable, unmonitored and without emergency stabilisation.

Climate impacts also affect living and intangible maritime heritage. Fisherfolk communities hold localised knowledge of tides, currents, creeks, weather, fishing grounds, boatbuilding, navigation and coastal ecosystems. Sacred maritime landscapes and systems of custodianship link cultural practices to particular places (Raza *et al* 2023). Changes to fisheries, mangroves, settlements and access to the coast, together with disaster displacement and livelihood transformation can interrupt such relationships and weaken intergenerational knowledge transmission.

Climate change also poses unique risks to underwater cultural heritage. Shipwrecks, submerged settlements and archaeological deposits may survive due to their presence in relatively stable seabed environments (**Fig. 2**). Changes to currents, storm intensity, sediment transport, temperature and biological activity can alter such preservation conditions (UNESCO 2025). Scour can expose previously buried remains, while erosion and storm events may displace artefacts or destabilise wreck structures. Conversely, changing sedimentation could rebury archaeological sites. Risks to underwater heritage are more closely tied to localised changing seabed and preservation environments, rather than broader sea-level rise, as the principal hazard.

Adaptation and risk reduction

Climate-resilient heritage management should begin with systematic assessment of the hazards, exposure, vulnerability and adaptive capacity, consistent with the IPCC framework. Much of Pakistan's coastal and underwater heritage remains poorly documented, therefore improved inventories and baseline recording are essential. Archaeological data should be integrated with GIS, historical charts, bathymetry data and sea-level projections.

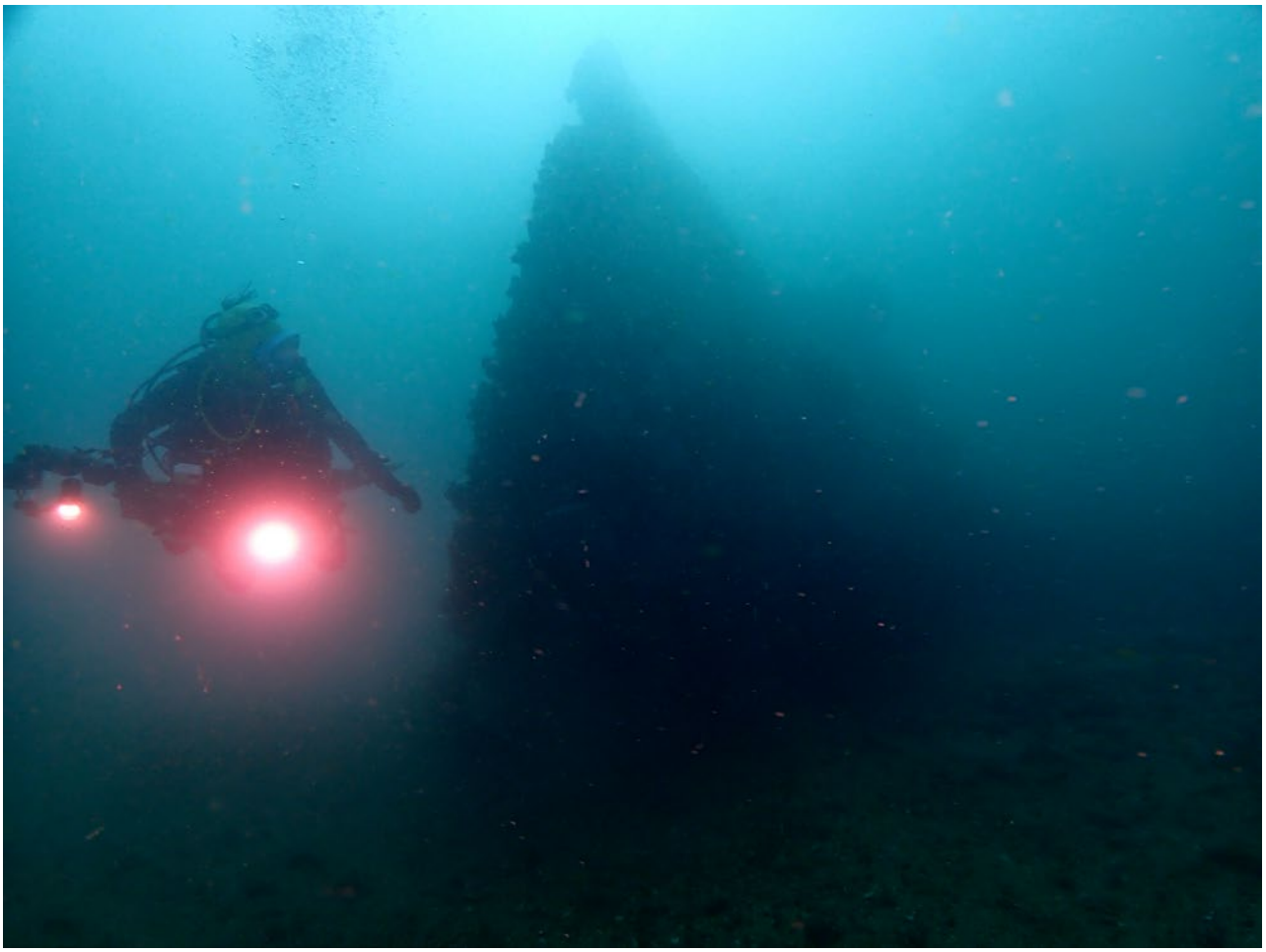


Figure 2- Recording of shipwrecks in the coastal waters of Pakistan (courtesy MaritimEA 2023).

One Pakistan example is MaritimEA Research's *Digital Heritage Trails Project* which produced high-resolution georeferenced photogrammetric documentation of *Banbhore*, *Ratukot*, *Jam Jaskar Goth*, *Ranokot* and *Lahiri Bandar* (**Fig. 3**). The resulting three-dimensional records establish measurable baselines against which erosion, structural deterioration and landscape change can be assessed. The British Council's Cultural Protection Fund highlighted the project as an example of digital preservation of sites vulnerable to erosion associated with rising sea levels and the project was endorsed as Decade Project by the United Nations Decade of Ocean Science for Sustainable Development (2021-2030). Underwater documentation was subsequently also undertaken at the site of Lahiri Bandar which may yet be extended into a long-term coastal heritage monitoring programme.

Adaptation should also be community-led and knowledge-inclusive. Fisherfolk knowledge can complement remote sensing observations. Protection of navigation knowledge, boatbuilding, fishing practices, oral histories and sacred geographies should, where possible, be integrated within established heritage documentation and protection regimes.

Heritage must also be incorporated into disaster-risk reduction and coastal planning. Heritage authorities require rapid post-disaster assessment procedures, emergency documentation protocols, inventories and stronger coordination with coastal, environmental and disaster-management agencies. Underwater cultural heritage inventories should inform dredging, harbour development and coastal engineering, consistent with the protection principles of the UNESCO 2001 Convention on the Protection of the Underwater Cultural Heritage.

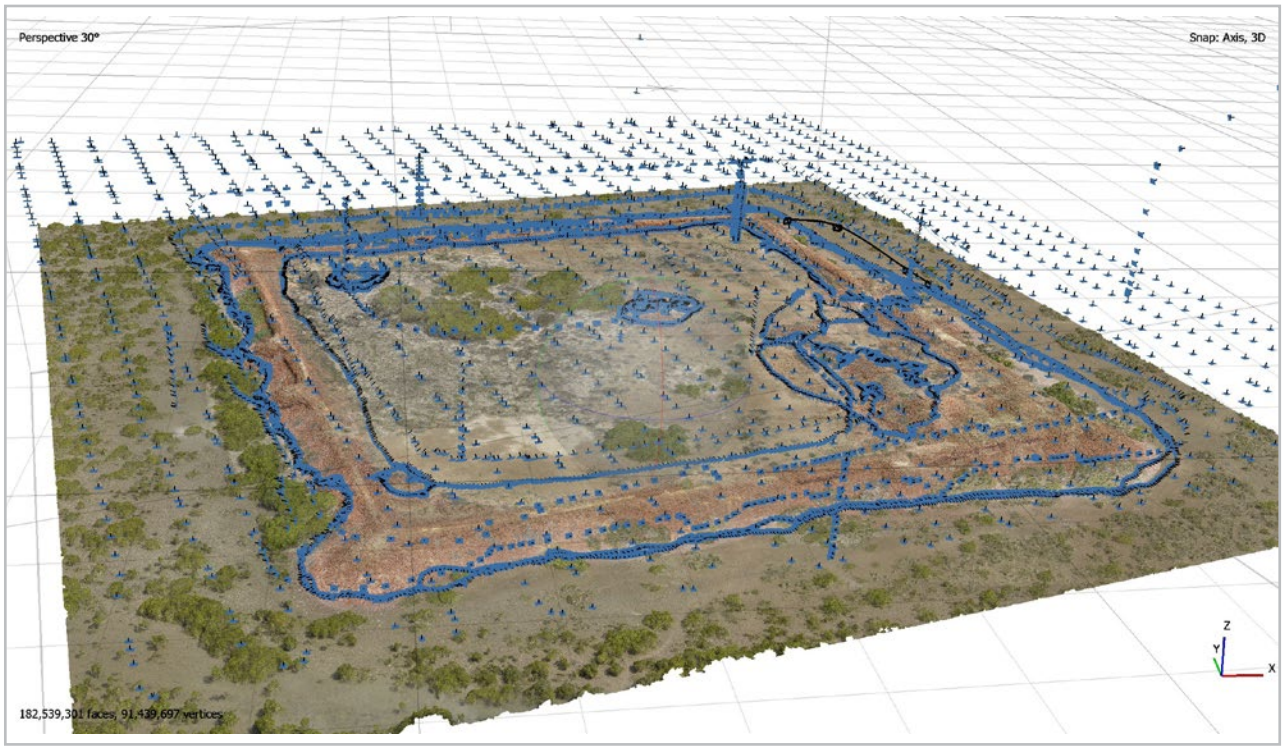


Figure 3- 3D reconstructions of archaeological sites such as Lahiri Bandar in the Indus delta (courtesy MaritimEA 2025).

Finally, climate adaptation must acknowledge limits to adaptation and residual risk. Preservation *in situ* should remain a preferred objective where feasible, but accelerating environmental transformation may make indefinite preservation impossible in some locations. Responses may range from protection and monitoring to archaeological investigation, digital documentation and managed change. For Pakistan, the challenge is not simply to defend individual monuments against climate hazards, but to manage dynamic maritime cultural landscapes in which coastal archaeology, underwater heritage, ecosystems and living traditions are interconnected.

MaritimEA is a grant funded research organisation with expertise in cultural heritage management, maritime archaeology, intangible cultural heritage documentation, community engagement, and blue economy master-planning. We support the aims of the 2001 UNESCO Convention on the Protection of the Underwater Cultural Heritage and the UN Ocean Decade (2021-2030).



Amer Bazl Khan is the founder and director of MaritimEA Research. He is a Maritime Archaeologist with over 20 years experience working in Pakistan and the broader Asia-Pacific region. Amer has worked extensively on underwater archaeological site investigations, cultural heritage management, maritime heritage protection policy, marine protected area management, and regional capacity development initiatives.

He is an expert member of the ICOMOS International Committee on the Underwater Cultural Heritage (ICUCH) and is also a member of the ICOMOS Pakistan National Committee. Amer is Vice President of the Nautical Archaeological Society in the UK and has served on the Executive Council and as Vice President of the Australasian Institute of Maritime Archaeology. He is also the South Asian regional representative for the Ocean Decade Heritage Network, a recognised partner of the UN's Decade of Ocean Science for Sustainable Development 2021-2030 and member of the Maritime Archaeology Committee of the International Congress of Maritime Museums. Amer is an active scuba diver and enjoys exploring shipwrecks in his free time.

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Climate Change, Severe Weather, and Underwater Cultural Heritage in the Gulf of Oman: Lessons from the World Heritage Site of Qalhat

Emad Khalil

Climate change is increasingly recognised as one of the principal threats facing coastal and underwater cultural heritage worldwide (Perez-Alvaro, 2016). Rising sea levels, changing storm regimes, coastal erosion, altered sediment dynamics, and extreme weather events are accelerating the degradation of archaeological landscapes, particularly along low-lying and dynamic coastlines (Breen, 2025). While considerable attention has focused on Europe and the Mediterranean, relatively little research has examined these impacts within the Arabian Peninsula, despite the region's long maritime history and the growing exposure of its coastal heritage to climate-related hazards.

The town of Qalhat, located on the Gulf of Oman and inscribed on the UNESCO World Heritage List in 2018 (UNESCO-WHC, 2018), provides an important case study for understanding these emerging challenges (**Fig. 1**).

Flourishing between the eleventh and sixteenth centuries AD, Qalhat served as one of the principal maritime centres connecting Oman with East Africa, India, the Arabian Gulf and China through the Indian Ocean trading network (Rougeulle, 2023). Its archaeological significance extends beyond the terrestrial remains of the medieval city to include an extensive underwater cultural landscape consisting of harbour areas, anchorage zones and submerged archaeological material documented along the adjacent coastline.

This paper draws upon the results of the UNESCO Scientific and Technical Advisory Body (STAB) mission undertaken at Qalhat in 2024 to examine how climate-driven coastal processes are affecting both the coastal and submerged archaeological record (UNESCO-STAB, 2025). Hence, the paper evaluates the site's exposure, vulnerability and adaptive capacity while proposing management measures that integrate climate adaptation into heritage conservation.

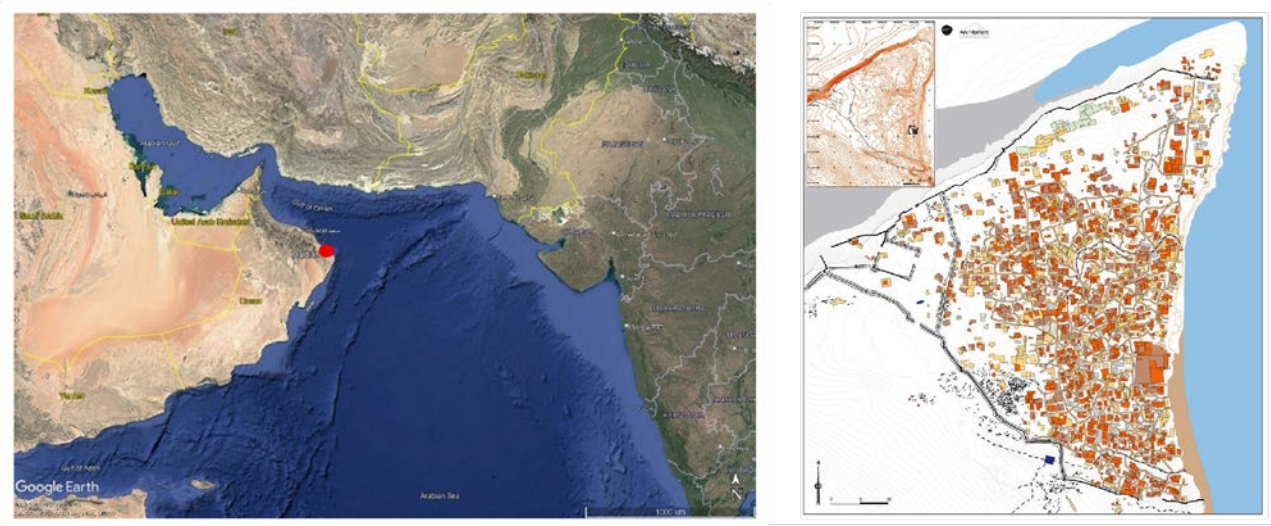


Figure 1- (Left) The location of the medieval town of Qalhat on the coast of Oman, illustrating its geographical setting within the northwestern Indian Ocean. (Source: Google Earth, adapted by the author). (Right) A map of the archaeological remain of the medieval town of Qalhat (Rougeulle, 2023, pp. 7).

Climate Change and the Vulnerability of Qalhat

Qalhat occupies an environmentally dynamic sector of the Omani coastline, where rocky headlands alternate with gravel beaches. Immediately north of the historic town, Wadi Hilm debouches into the Gulf of Oman through a seasonal wadi mouth, forming an embayment widely considered to have served as the city's natural harbour (**Fig. 2**).

This geomorphologically active setting has shaped the coastal landscape for centuries and continues to influence its evolution today. The harbour environment is subject to continual morphological change resulting from the interaction of seasonal wadi discharge, sediment transport, wave energy, and coastal currents. During periods of heavy rainfall, Wadi Hilm delivers large volumes of sediment to the coast through its outlet, while marine processes subsequently redistribute these deposits along the shoreline, modifying beach morphology, nearshore bathymetry, and the configuration of the harbour itself. Consequently, the position and character of the harbour have likely changed repeatedly over time. These dynamic coastal processes not only influence the preservation of archaeological deposits but also complicate the reconstruction of the ancient maritime landscape, as former shoreline positions, harbour features, and submerged archaeological remains may have been buried, eroded, or displaced.

Satellite imagery spanning the last two decades demonstrates repeated cycles of erosion and sediment deposition that periodically alter the embayment's entrance and reshape its configuration (**Fig. 3**).

The principal climate-related drivers affecting the Arabian Sea include sea-level rise, ocean warming, extreme



Figure 2- (Left) The bay adjacent to Qalhat served as the city's natural harbour. The bay also receives the seasonal discharge of Wadi Hilm. (Right) The shoreline at Qalhat, showing the gravel beach and the adjacent cliffs, where coastal erosion, sediment redistribution, and wave action pose increasing challenges to the preservation of the archaeological landscape. (Photograph by Asma El-Saied).

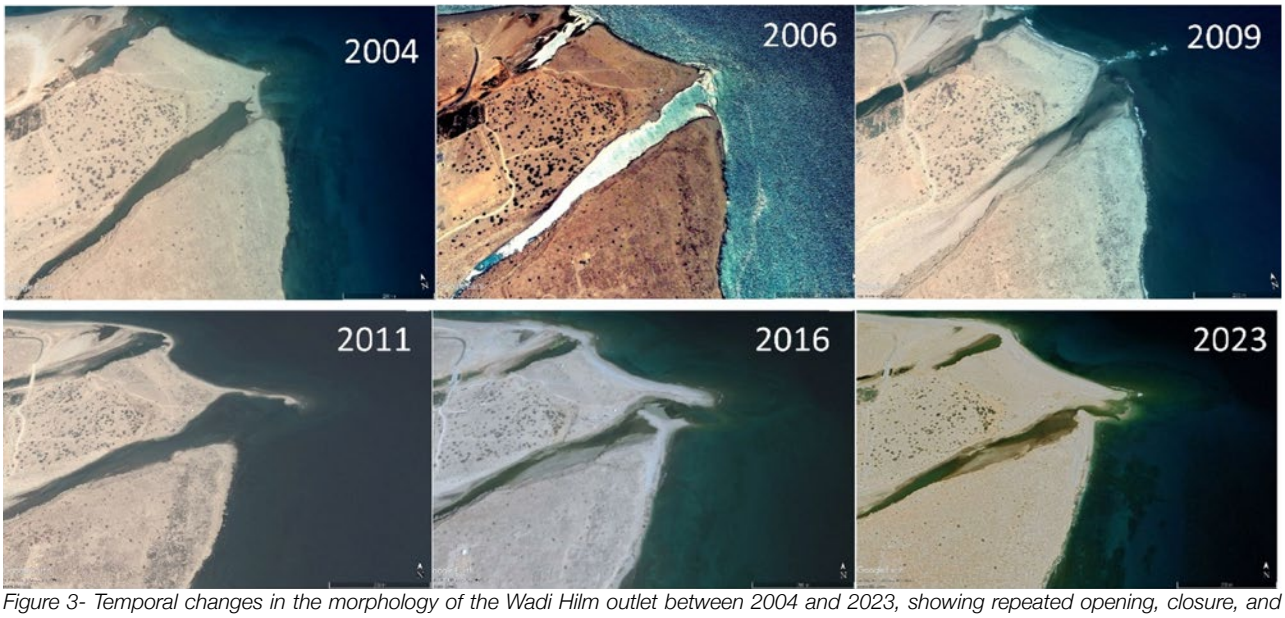


Figure 3- Temporal changes in the morphology of the Wadi Hilm outlet between 2004 and 2023, showing repeated opening, closure, and migration of the channel as a result of sediment redistribution and episodic flooding. (Source: Google Earth, compiled by the author).

rainfall events (Pörtner *et al*., 2022, pp. 2055), and increasingly intense tropical cyclones (Bell *et al*. 2020, pp. 6499).

Along the Omani coast, these processes accelerate coastal erosion, increase wave energy, and intensify sediment transport from wadis, posing significant threats to archaeological preservation and the long-term stability of coastal landscapes. These regional processes interact with the seasonal southwest monsoon, during which persistent high-energy waves dominate the Gulf of Oman coastline, accelerating coastal erosion, cliff instability and the redistribution of nearshore sediments.

Hence, Qalhat demonstrates high exposure because significant archaeological remains are located directly within the active coastal zone, while its underwater heritage occupies shallow waters particularly susceptible to wave action and sediment movement. Its vulnerability is increased by the absence of systematic long-term environmental monitoring.

The underwater survey undertaken in 2024, as part of the UNESCO (STAB) mission, documented seven stone anchors distributed in two distinct clusters along the coast, confirming the importance of the area as a medieval anchorage (**Fig. 4**) (UNESCO UCH, 2025, pp. 18-21).

However, previous investigations of the area in the 1990s had identified fifteen anchors in approximately the same area (Vosmer 1999). The inability to relocate more than half of these previously recorded anchors strongly suggests extensive sediment burial rather than their physical removal.

This observation provides one of the clearest archaeological indicators of changing sediment dynamics at Qalhat. Sediment accumulation, driven by seasonal runoff and coastal transport processes, progressively buries underwater archaeological material, preventing its documentation, monitoring and conservation. Although burial may offer temporary physical protection, continued sediment movement also increases the risk of displacement, abrasion and eventual loss.

Equally significant were the observations made during the shoreline investigation. Numerous sections of the coastline displayed clear evidence of marine erosion, with portions of archaeological deposits and coastal cliffs collapsing into the sea under the action of high-energy waves (**Fig. 5**). These processes appear particularly active during the southwest monsoon and periods of cyclonic activity, when rough sea conditions substantially increase wave energy impacting the shoreline.

Accordingly, it becomes apparent that the inability to relocate several previously documented stone anchors, together with the observed collapse of coastal cliffs and the recurrent opening and closure of the mouth of

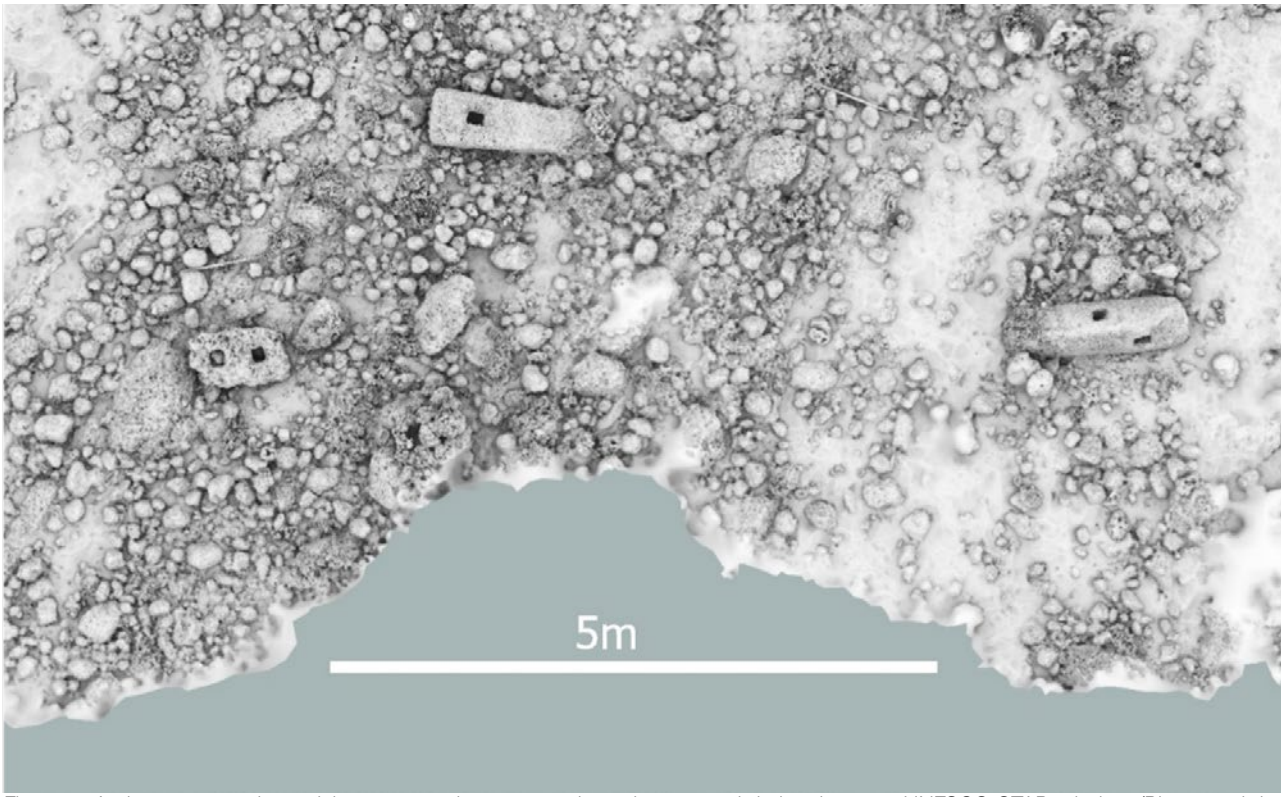


Figure 4- A photogrammetric model of some of the stone anchors documented during the 2024 UNESCO-STAB mission. (Photograph by Mohamed Salama).



Figure 5- Wave-induced erosion of the coastal cliffs at Qalhat results in periodic cliff collapse, posing an ongoing threat to archaeological deposits located along the shoreline. (Photograph by the author).

Wadi Hilm, provides direct archaeological evidence of ongoing geomorphological change at Qalhat. Erosion and sediment transport are simultaneously removing, burying, and redistributing archaeological material, complicating the interpretation and management of both terrestrial and submerged remains. These processes are likely to intensify due to the increase in extreme rainfall, wave energy, and coastal erosion associated with climate change.

Adaptation and Heritage Management

Current adaptive measures remain comparatively limited. Although inscription on the World Heritage List has increased international recognition of the site, comprehensive climate adaptation measures have yet to be incorporated into the site's management framework. Consequently, the overall climate risk to both coastal and underwater archaeological resources should be regarded as high.

Improving the resilience of Qalhat requires integrating climate adaptation into routine heritage management. Continuous shoreline monitoring using remote sensing, photogrammetry and repeated satellite analysis should be combined with periodic underwater archaeological surveys to identify changes in sediment distribution and erosion rates. Geophysical investigations employing sub-bottom profilers would assist in locating archaeological material buried beneath recent sediment deposits, while sediment coring within Wadi Hilm would improve understanding of long-term harbour evolution.

Regular vulnerability assessments should be incorporated into the site's management plan, enabling conservation priorities to respond to changing environmental conditions. Engineering interventions, such as carefully designed offshore breakwaters protecting the most vulnerable shoreline sectors, may also reduce wave energy where archaeological deposits face immediate risk, provided such measures are supported by detailed environmental impact assessments.

Interdisciplinary collaboration between archaeologists, coastal geomorphologists, climate scientists and heritage managers will be essential for developing evidence-based responses to future environmental change.

Conclusion

Qalhat illustrates how climate change is transforming archaeological landscapes throughout the Gulf of Oman. The 2024 underwater archaeological survey demonstrates that coastal erosion, increasing wave action and accelerated sediment redistribution are already affecting both coastal and submerged cultural heritage.

Accordingly, Qalhat represents a highly exposed and vulnerable coastal heritage landscape whose long-term preservation depends upon integrating climate adaptation into heritage management. Beyond its importance for Oman, the site offers valuable lessons for numerous historic ports and coastal archaeological landscapes throughout the Arabian Peninsula, demonstrating the urgent need to combine archaeological investigation with climate science in order to safeguard underwater cultural heritage in an era of accelerating environmental change.

The Alexandria Centre for Maritime Archaeology and Underwater Cultural Heritage

The Alexandria Centre for Maritime Archaeology and Underwater Cultural Heritage (CMAUCH) was established at Alexandria University in 2009. It hosts the UNESCO Chair on Underwater Cultural Heritage and plays a significant regional role in advancing the education, research, protection, management, and public understanding of maritime and underwater cultural heritage.
The Centre provides specialized postgraduate education and professional training, undertakes archaeological research and field projects, and contributes to regional capacity building through training programmes, institutional partnerships, and international cooperation. It also promotes public education and community engagement through conferences, exhibitions, awareness campaigns, and outreach activities aimed at making underwater cultural heritage more accessible to wider audiences.



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He is a member of UNESCO's Scientific and Technical Advisory Body for the 2001 Convention, a member of ICOMOS-ICUCH, and Director of Scientific Diving at CMAS. His previous leadership roles include Founding Director of the Alexandria University Centre for Maritime Archaeology and Underwater Cultural Heritage, Director of the Alexandria and Mediterranean Research Center at the Bibliotheca Alexandrina, and Deputy Director of the Institute of Nautical Archaeology–Egypt.
Professor Khalil has led and advised numerous heritage initiatives across the Arab region and internationally. He has authored more than forty publications in Arabic and English, focusing on heritage management, institutional development, international cooperation, and the integration of cultural heritage into sustainable development and public policy.
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Environmental Change and Underwater Cultural Heritage in War-Affected Ukraine: Challenges for Heritage Management

Dmytro Kobaliia, and *Mykhailo Mulenko*

Since the beginning of Russia's full-scale invasion of Ukraine, dramatic human induced environmental changes have occurred which pose significant additional challenges to managing the country's underwater cultural heritage (UCH) under a changing climate.

Ukraine possesses extensive and diverse UCH, but it remains poorly studied. It includes shipwrecks, submerged settlements and cemeteries, crossings, fords, port facilities, anchorages, and dugout boats. The large number of submerged terrestrial sites is largely a consequence of twentieth-century dam construction. Ukraine's UCH sites also reflect the region's complex political and cultural history, connecting the Black Sea, the Eurasian Steppe, and Central and Eastern Europe.

Climate change is already affecting Ukraine, with observed warming of up to 3 °C, a decrease in the duration but an increase in the intensity of precipitation events, and an overall decline in river discharge relative to pre-industrial levels (Vyshnevskyi, 2025).

However, probably the most dramatic recent change have occurred on the Dnipro River. After the destruction of Kakhovka Hydroelectric Power Plant (HPP) on June 6, 2023, the reservoir rapidly disappeared and the river returned toward its pre-dam hydrological regime. Within a year, the reservoir's area decreased by 91 percent and its water volume by 96 percent. Two interconnected processes now affect archaeological heritage: the drying of formerly flooded territories and changes in river flow below Zaporizhzhia.

The first process has transformed many underwater sites into terrestrial ones. Hundreds of settlements and burial sites, dating to the Late Palaeolithic up to the 20th century, have become accessible. Among the most important are sites connected with the Zaporizhian Siches. This group of sites, combined functions as a military camp, an administrative and political center, and a fortified stronghold of the Zaporozhian Cossacks in the sixteenth to eighteen century, and the historical landscape of the Great Meadow (a sacred landscape of Ukrainian history, identified by Herodotus as Scythian Hylaea, and the birthplace of the Zaporozhian Cossacks). The drying of sites that had previously been on land is not, in itself, a problem. The problem is that the "new-old" shoreline remains active and unstable because of the altered hydrological regime and absence of vegetation. This zone may be only tens of meters wide, but extends for hundreds of kilometers. These areas had not previously been systematically surveyed, while many sites remain outside official databases and state monitoring.

It should be noted that the shallowing process of the Kakhovka Reservoir was catastrophic and uncontrollable in nature, with a water level drop rate of up to 12 cm per hour. Under these conditions, the resulting current caused a significant reduction in the thickness of soft muddy deposits across previously flooded areas, which in turn exposed archaeological sites buried beneath them. On the other hand, it triggered an environmental disaster of international significance, resulting in the mortality of numerous living organisms, the loss of established habitats, and unprecedented organic pollution and desalination of the Black Sea water

area, including its western coastal zones (Kuzemko *et al*. 2026).

The nearly 300 kilometers of shoreline exposed along the river can be broadly divided into two zones. The first, extending from Kakhovka toward Zaporizhzhia, forms part of the frontline and is closed to access, making archaeological monitoring currently almost impossible. The second is a relatively small area around Zaporizhzhia, where shoreline surveys are being conducted by the National Reserve "Khortytsia" (**Fig. 1**). By 2026, these surveys had documented numerous archaeological finds, including ship fragments, dugout boats, and settlement sites (Kobaliia 2026).



Figure 1- Protection of one of the objects on the shore of Khortytsia from drying out. In 2025, the vessel fragment was investigated and relocated to a conservation site (credit: Uglanov Sergey; image: public domain).

The ecological transformation has also created new possibilities for underwater survey. Before 2023, standing water, poor visibility, heavy silting, and thick Dreissena mussel colonies made archaeological work difficult. Today, flowing water is clearer and accumulated silt is gradually being removed. Archaeological work in the early 2000s showed that old riverbeds preserved their relief beneath reservoir sediments, but visibility was often less than one meter and could fall to zero in summer (Kobaliia, Ostapenko, and Demenko 2008). The new hydrological regime fundamentally changes these conditions. Research strategies must therefore combine discovery with rescue archaeology: newly visible sites cannot simply be treated as new opportunities, because exposure itself may be the process destroying them.

The second process presents a more immediate threat. Seasonal floods below the dam in Zaporizhzhia cause erosion, move sediments, expose wooden wrecks, and disperse archaeological material (**Fig. 2**). The shoreline has returned to its natural contours but has also become more dependent on seasonal fluctuations in water level.



Figure 2- The remains of one of the early 20th-century flat-bottomed ferries, exposed by the current of the Dnipro River near Khortytsia Island. (credit: Uglanov Sergey; images: public domain).

Furthermore, apart from the fact that the Dnipro River upstream of Zaporizhzhia remains regulated—meaning that the entire volume of annual runoff is controlled by the hydraulic engineering regulations of several hydroelectric power plants—the water availability of the area freed from the reservoir has decreased compared to the historical period prior to its creation. This leads to numerous instances where typical underwater archaeological sites find themselves either directly on dry land or within the zone of an unstable coastal hydrological regime.

Earlier floods demonstrate the potential scale of this process. In 1998, a major release of water below the Zaporizhzhia dam shifted large quantities of sand and exposed wrecks of the Dnipro flotilla near Khortytsia (**Fig. 3**). The flotilla of approximately 400 vessels was built to support logistical and military operations against the Ottoman fleet in the lower reaches of the Dnipro River between 1736 and 1739. These wrecks show how quickly exposed waterlogged wood can deteriorate (Kobaliia 2016). Protected by sand and silt for centuries, timber may retain its form and physical properties. Once sediments are removed, weakened fastenings fail hull structures disintegrate, and fragments are transported downstream. Large structural elements can also be damaged by the mass of sediment accumulated inside them, as observed at many sites excavated underwater and in the coastal zone. The hydrological changes that have

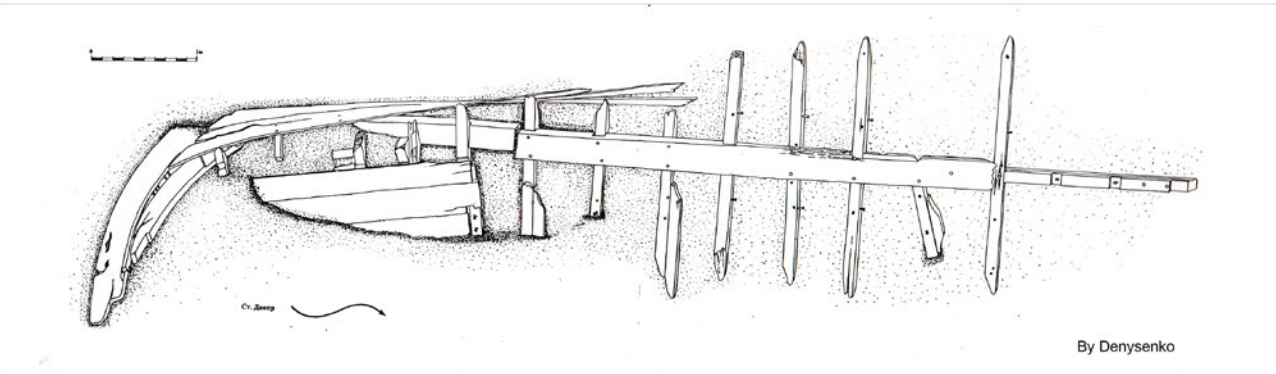


Figure 3- The bow section of a 1737 military vessel on the riverbed near Naum Rock was investigated following severe erosion of the site in 1999. (credit: Denysenko Andrew; image: public domain).

continued since 2023 pose a serious threat to both the preservation and the spatial integrity of archaeological complexes.

Today, new natural complexes are actively forming in the territory of the historical Velykyi Luh (Great Meadow) freed from water, a significant part of which consists of young willow-poplar forests that scientists already refer to as the largest floodplain forest in Europe. Not only the area of these plant communities is striking (over 650 sq km), but also their growth rates. As of October 2026, the average height of young willows is 7 m, with the maximum exceeding 9 m. At the same time, a high density of spatial distribution of these trees is maintained, averaging from 2 to 5 individuals per 1 sq m. Herbaceous formations are also characterized by significant development, already numbering over 400 species of vascular plants. While ecologists perceive this as a true miracle, from the perspective of archaeological heritage preservation, this process can negatively affect both the direct condition of the site and its potential destruction, as well as the process of discovery, since search operations will be significantly complicated given such density and plant parameters (Didukh *et al*. 2025).

The destruction of the Kakhovka HPP has therefore created both serious threats and exceptional opportunities for archaeological research. Wooden wrecks and other sites exposed by erosion may deteriorate rapidly, while the displacement of artefacts by currents can result in the irreversible loss of archaeological context. At the same time, the transformed river system has made large areas of the former Dnipro riverbed and previously submerged landscapes accessible to systematic investigation for the first time in decades (**Fig. 4**).



Figure 4- Velykyi Luh (Great Meadow) after the water receded in 2024. (credit: Tynny; image: public domain).

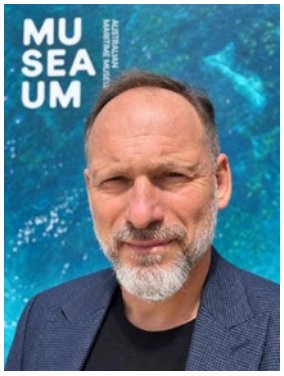
The central long-term question is whether the Kakhovka dam and reservoir will be restored. The reservoir flooded an enormous territory important to Ukraine's historical memory and natural heritage. Its disappearance has allowed the Great Meadow ecosystem to begin recovering and has reopened archaeological landscapes inaccessible since the Soviet period. Navigation, irrigation, electricity generation, and cooling for Zaporizhzhia Nuclear Power Plant were among the functions associated with the reservoir, but alternatives based on modern technologies should be considered when decisions about its future are made. This is particularly important in light of projected climate change impacts, with modelling indicating that river discharge in the Dnipro River could decline by up to 24% under the RCP 8.5 scenario (Didovets *et al*., 2020).

Whatever solution is chosen, archaeology and heritage protection need to be included from the beginning. Any reconstruction, river engineering,

dredging, or restoration of irrigation infrastructure would require comprehensive archaeological survey. Equally, preserving the present hydrological regime would demand large-scale documentation, conservation, monitoring, and protection of newly exposed sites. This is a significant challenge as a new baseline for the river will need to be established, in order to facilitate better understanding of its present and future behavior. This will require trained specialists, monitoring equipment, conservation facilities, reliable documentation, and sustained international cooperation, particularly for fragile waterlogged materials requiring immediate stabilization, but also for long-term management of UCH.

Naturally, all such activities should be conducted in accordance with the UNESCO *Convention on the Protection of the Underwater Cultural Heritage*, ratified by Ukraine in 2006, and with the national legal framework governing cultural heritage protection, particularly the Law of Ukraine "On the Protection of Archaeological Heritage" (2004) and the Law of Ukraine "On the Protection of Cultural Heritage" (2000).

The war has transformed the underwater cultural heritage of southern Ukraine at a landscape scale, both at present and for the medium term. Sites once protected beneath water and sediment are now exposed: other sites are being eroded and redistributed by stronger currents. Yet these processes also provide an unprecedented opportunity to study the Dnipro, the Great Meadow, and archaeological sites inaccessible for generations. The immediate task is to document and protect what survives while developing a long-term strategy combining archaeological research, conservation, climate risk assessment, environmental recovery, and postwar reconstruction.



Dmitry Kobaliia, PhD, is a Ukrainian archaeologist specializing in underwater cultural heritage, maritime archaeology, and the history of shipbuilding. Since 2005, he has headed the Department for Monument Protection at the National Reserve "Khortytsia" in Zaporizhzhia, Ukraine. His research focuses on the maritime and naval history of the Dnipro and Black Sea regions, particularly shipbuilding and naval activity of the seventeenth and eighteenth centuries.

He has directed and participated in numerous archaeological and underwater investigations, including the study of historic vessels discovered near Khortytsia and research prompted by the dramatic environmental changes following the destruction of the Kakhovka Dam in 2023. His current work combines archaeological research, documentation, conservation, and emergency safeguarding of cultural heritage affected by war.

Kobaliia is a Research Associate of the Institute of Nautical Archaeology and an Associate Member of the International Congress of Maritime Museums. He is also involved in international projects focused on underwater heritage research, professional training, and museum cooperation.

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Mykhailo Mulenko is a Ukrainian biologist, GIS specialist, and conservationist serving as the Head of the Nature Protection Department at the National Reserve Khortytsia. He holds a degree in biology and completed postgraduate studies in zoology at Zaporizhzhia National University.

With extensive experience in environmental monitoring and project management, he leads initiatives focused on ecosystem preservation and the documentation of conflict impacts on natural and cultural heritage. He actively collaborates with international and state institutions, including UNESCO, and contributes his scientific expertise to documentary projects, contemporary art, and environmental restoration efforts.

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APPENDICES



Photo Credit: Part of the roman lead anchor from the 1st century AD, shipwreck Letavica on the island Pag (photo: M. Pešić).

APPENDIX I: ICOMOS CHARTER ON THE PROTECTION AND MANAGEMENT OF UNDERWATER CULTURAL HERITAGE (SOFIA 1996)

ICOMOS

Charter on the Protection and Management of Underwater Cultural Heritage (ratified by the 11th ICOMOS General Assembly, held in Sofia, Bulgaria, from 5th – 9th October, 1996)

INTRODUCTION

This Charter is intended to encourage the protection and management of underwater cultural heritage in inland and inshore waters, in shallow seas and in the deep oceans.

It focuses on the specific attributes and circumstances of cultural heritage under water and should be understood as a supplement to the ICOMOS Charter for the Protection and Management of Archaeological Heritage, 1990. The 1990 Charter defines the "archaeological heritage" as that part of the material heritage in respect of which archaeological methods provide primary information, comprising all vestiges of human existence and consisting of places relating to all manifestations of human activity, abandoned structures, and remains of all kinds, together with all the portable cultural material associated with them. For the purposes of this Charter underwater cultural heritage is understood to mean the archaeological heritage which is in, or has been removed from, an underwater environment. It includes submerged sites and structures, wreck-sites and wreckage and their archaeological and natural context.

By its very character the underwater cultural heritage is an international resource. A large part of the underwater cultural heritage is located in an international setting and derives from international trade and communication in which ships and their contents are lost at a distance from their origin or destination.

Archaeology is concerned with environmental conservation; in the language of resource management, underwater cultural heritage is both finite and non-renewable. If underwater cultural heritage is to contribute to our appreciation of the environment in the future, then we have to take individual and collective responsibility in the present for ensuring its continued survival.

Archaeology is a public activity; everybody is entitled to draw upon the past in informing their own lives, and every effort to curtail knowledge of the past is an infringement of personal autonomy.
Underwater cultural heritage contributes to the formation of identity and can be important to people's sense of community.

If managed sensitively, underwater cultural heritage can play a positive role in the promotion of recreation and tourism.

Archaeology is driven by research, it adds to knowledge of the diversity of human culture through the ages and it provides new and challenging ideas about life in the past.

Such knowledge and ideas contribute to understanding life today and, thereby, to anticipating future challenges.
Many marine activities, which are themselves beneficial and desirable, can have unfortunate consequences for underwater cultural heritage if their effects are not foreseen.
Underwater cultural heritage may be threatened by construction work that alters the shore and seabed or alters the flow of current, sediment and pollutants. Underwater cultural heritage may also be threatened by insensitive exploitation of living and non-living resources. Furthermore, inappropriate forms of access and the incremental impact of removing "souvenirs" can have a deleterious effect.

Many of these threats can be removed or substantially reduced by early consultation with archaeologists and by implementing mitigatory projects. This Charter is intended to assist in bringing a high standard of archaeological expertise to bear on such threats to underwater cultural heritage in a prompt and efficient manner.

Underwater cultural heritage is also threatened by activities that are wholly undesirable because they are intended to profit few at the expense of many. Commercial exploitation of underwater cultural heritage for trade or speculation is fundamentally incompatible with the protection and management of the heritage. This Charter is intended to ensure that all investigations are explicit in their aims, methodology and anticipated results so that the intention of each project is transparent to all.

Article 1 - Fundamental Principles

The preservation of underwater cultural heritage in situ should be considered as a first option.

Public access should be encouraged.

Non-destructive techniques, non-intrusive survey and sampling should be encouraged in preference to excavation.

Investigation must not adversely impact the underwater cultural heritage more than is necessary for the mitigatory or research objectives of the project.

Investigation must avoid unnecessary disturbance of human remains or venerated sites.

Investigation must be accompanied by adequate documentation.

Article 2 - Project Design

Prior to investigation a project must be prepared, taking into account :

- the mitigatory or research objectives of the project;
- the methodology to be used and the techniques to be employed;
- anticipated funding;
- the time-table for completing the project;
- the composition, qualifications, responsibility and experience of the investigating team;
- material conservation;
- site management and maintenance;
- arrangements for collaboration with museums and other institutions;
- documentation;
- health and safety;
- report preparation;
- deposition of archives, including underwater cultural heritage removed during investigation;
- dissemination, including public participation.

The project design should be revised and amended as necessary.

Investigation must be carried out in accordance with the project design. The project design should be made available to the archaeological community.

Article 3 - Funding

Adequate funds must be assured in advance of investigation to complete all stages of the project design including conservation, report preparation and dissemination. The project design should include contingency plans that will ensure conservation of underwater cultural heritage and supporting documentation in the event of any interruption in anticipated funding.

Project funding must not require the sale of underwater cultural heritage or the use of any strategy that will cause underwater cultural heritage and supporting documentation to be irretrievably dispersed.

Article 4 - Time-table

Adequate time must be assured in advance of investigation to complete all stages of the project design including conservation, report preparation and dissemination. The project design should include contingency plans that will ensure conservation of underwater cultural heritage and supporting documentation in the event of any interruption in anticipated timings.

Article 5- Research objectives, methodology and techniques

Research objectives and the details of the methodology and techniques to be employed must be set down in the project design. The methodology should accord with the research objectives of the investigation and the techniques employed must be as unintrusive as possible.

Post-fieldwork analysis of artefacts and documentation is integral to all investigation; adequate provision for this analysis must be made in the project design.

Article 6 - Qualifications, responsibility and experience

All persons on the investigating team must be suitably qualified and experienced for their project roles. They must be fully briefed and understand the work required.

All intrusive investigations of underwater cultural heritage will only be undertaken under the direction and control of a named underwater archaeologist with recognised qualifications and experience appropriate to the investigation.

Article 7 - Preliminary investigation

All intrusive investigations of underwater cultural heritage must be preceded and informed by a site assessment that evaluates the vulnerability, significance and potential of the site.

The site assessment must encompass background studies of available historical and archaeological evidence, the archaeological and environmental characteristics of the site and the consequences of the intrusion for the long term stability of the area affected by investigations.

Article 8 - Documentation

All investigation must be thoroughly documented in accordance with current professional standards of archaeological documentation.

Documentation must provide a comprehensive record of the site, which includes the provenance of underwater cultural heritage moved or removed in the course of investigation, field notes, plans and drawings, photographs and records in other media.

Article 9 - Material conservation

The material conservation programme must provide for treatment of archaeological remains during investigation, in transit and in the long term.

Material conservation must be carried out in accordance with current professional standards.

Article 10 - Site management and maintenance

A programme of site management must be prepared, detailing measures for protecting and managing in situ underwater cultural heritage in the course of an upon termination of fieldwork. The programme should include public information, reasonable provision for site stabilisation, monitoring and protection against interference.
Public access to in situ underwater cultural heritage should be promoted, except where access is incompatible with protection and management.

Article 11 - Health and safety

The health and safety of the investigating team and third parties is paramount. All persons on the investigating team must work according to a safety policy that satisfies relevant statutory and professional requirements and is set out in the project design.

Article 12 - Reporting

Interim reports should be made available according to a time-table set out in the project design, and deposited in relevant public records.
Reports should include:

- an account of the objectives;
- an account of the methodology and techniques employed;
- an account of the results achieved;
- recommendations concerning future research, site management and curation of underwater cultural heritage removed during the investigation.

Article 13 - Curation

The project archive, which includes underwater cultural heritage removed during investigation and a copy of all supporting documentation, must be deposited in an institution that can provide for public access and permanent curation of the archive. Arrangements for deposition of the archive should be agreed before investigation commences, and should be set out in the project design. The archive should be prepared in accordance with current professional standards.

The scientific integrity of the project archive must be assured; deposition in a number of institutions must not preclude reassembly to allow further research.

Underwater cultural heritage is not to be traded as items of commercial value.

Article 14 - Dissemination

Public awareness of the results of investigations and the significance of underwater cultural heritage should be promoted through popular presentation in a range of media. Access to such presentations by a wide audience should not be prejudiced by high charges.

Co-operation with local communities and groups is to be encouraged, as is co-operation with communities and groups that are particularly associated with the underwater cultural heritage concerned. It is desirable that investigations proceed with the consent and endorsement of such communities and groups.

The investigation team will seek to involve communities and interest groups in investigations to the extent that such involvement is compatible with protection and management. Where practical, the investigation team should provide opportunities for the public to develop archaeological skills through training and education.
Collaboration with museums and other institutions is to be encouraged. Provision for visits, research and reports by collaborating institutions should be made in advance of investigation.

A final synthesis of the investigation must be made available as soon as possible, having regard to the complexity of the research, and deposited in relevant public records.

Article 15 - International co-operation

International co-operation is essential for protection and management of underwater cultural heritage and should be promoted in the interests of high standards of investigation and research. International co-operation should be encouraged in order to make effective use of archaeologists and other professionals who are specialised in investigations of underwater cultural heritage. Programmes for exchange of professionals should be considered as a means of disseminating best practice.

APPENDIX II: UNESCO CONVENTION ON THE PROTECTION OF THE UNDERWATER CULTURAL HERITAGE (PARIS 2001)

The General Conference of the United Nations Educational, Scientific and Cultural Organization, meeting in Paris from 15 October to 3 November 2001, at its 31st session,

Acknowledging the importance of underwater cultural heritage as an integral part of the cultural heritage of humanity and a particularly important element in the history of peoples, nations, and their relations with each other concerning their common heritage,

Realizing the importance of protecting and preserving the underwater cultural heritage and that responsibility therefor rests with all States,

Noting growing public interest in and public appreciation of underwater cultural heritage,
Convinced of the importance of research, information and education to the protection and preservation of underwater cultural heritage,

Convinced of the public's right to enjoy the educational and recreational benefits of responsible non-intrusive access to in situ underwater cultural heritage, and of the value of public education to contribute to awareness, appreciation and protection of that heritage,

Aware of the fact that underwater cultural heritage is threatened by unauthorized activities directed at it, and of the need for stronger measures to prevent such activities,

Conscious of the need to respond appropriately to the possible negative impact on underwater cultural heritage of legitimate activities that may incidentally affect it,

Deeply concerned by the increasing commercial exploitation of underwater cultural heritage, and in particular by certain activities aimed at the sale, acquisition or barter of underwater cultural heritage,
Aware of the availability of advanced technology that enhances discovery of and access to underwater cultural heritage,

Believing that cooperation among States, international organizations, scientific institutions, professional organizations, archaeologists, divers, other interested parties and the public at large is essential for the protection of underwater cultural heritage,

Considering that survey, excavation and protection of underwater cultural heritage necessitate the availability and application of special scientific methods and the use of suitable techniques and equipment as well as a high degree of professional specialization, all of which indicate a need for uniform governing criteria,

Realizing the need to codify and progressively develop rules relating to the protection and preservation of underwater cultural heritage in conformity with international law and practice, including the UNESCO Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property of 14 November 1970, the UNESCO Convention for the Protection of the World Cultural and Natural Heritage of 16 November 1972 and the United Nations Convention on the Law of the Sea of 10 December 1982,

Committed to improving the effectiveness of measures at international, regional and national levels for the preservation in situ or, if necessary for scientific or protective purposes, the careful recovery of underwater cultural heritage,

Having decided at its twenty-ninth session that this question should be made the subject of an international convention,
Adopts this second day of November 2001 this Convention.

Article 1 – Definitions

For the purposes of this Convention:
1. (a) "Underwater cultural heritage" means all traces of human existence having a cultural, historical or archaeological character which have been partially or totally under water, periodically or continuously, for at least 100 years such as:
(i) sites, structures, buildings, artefacts and human remains, together with their archaeological and natural context;

(ii) vessels, aircraft, other vehicles or any part thereof, their cargo or other contents, together with their archaeological and natural context; and

(iii) objects of prehistoric character.

(b) Pipelines and cables placed on the seabed shall not be considered as underwater cultural heritage.

(c) Installations other than pipelines and cables, placed on the seabed and still in use, shall not be considered as underwater cultural heritage.

2. (a) "States Parties" means States which have consented to be bound by this Convention and for which this Convention is in force.

(b) This Convention applies mutatis mutandis to those territories referred to in Article 26, paragraph 2(b), which become Parties to this Convention in accordance with the conditions set out in that paragraph, and to that extent "States Parties" refers to those territories.

3. "UNESCO" means the United Nations Educational, Scientific and Cultural Organization.

4. "Director-General" means the Director-General of UNESCO.

5. "Area" means the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction.

6. "Activities directed at underwater cultural heritage" means activities having underwater cultural heritage as their primary object and which may, directly or indirectly, physically disturb or otherwise damage underwater cultural heritage.

7. "Activities incidentally affecting underwater cultural heritage" means activities which, despite not having underwater cultural heritage as their primary object or one of their objects, may physically disturb or otherwise damage underwater cultural heritage.

8. "State vessels and aircraft" means warships, and other vessels or aircraft that were owned or operated by a State and used, at the time of sinking, only for government non-commercial purposes, that are identified as such and that meet the definition of underwater cultural heritage.

9. "Rules" means the Rules concerning activities directed at underwater cultural heritage, as referred to in Article 33 of this Convention.

Article 2 – Objectives and general principles

1. This Convention aims to ensure and strengthen the protection of underwater cultural heritage.

2. States Parties shall cooperate in the protection of underwater cultural heritage.

3. States Parties shall preserve underwater cultural heritage for the benefit of humanity in conformity with the provisions of this Convention.

4. States Parties shall, individually or jointly as appropriate, take all appropriate measures in conformity with this Convention and with international law that are necessary to protect underwater cultural heritage, using for this purpose the best practicable means at their disposal and in accordance with their capabilities.

5. The preservation in situ of underwater cultural heritage shall be considered as the first option before allowing or engaging in any activities directed at this heritage.

6. Recovered underwater cultural heritage shall be deposited, conserved and managed in a manner that ensures its long-term preservation.

7. Underwater cultural heritage shall not be commercially exploited.

8. Consistent with State practice and international law, including the United Nations Convention on the Law of the Sea, nothing in this Convention shall be interpreted as modifying the rules of international law and State practice pertaining to sovereign immunities, nor any State's rights with respect to its State vessels and aircraft.

9. States Parties shall ensure that proper respect is given to all human remains located in maritime waters.

10. Responsible non-intrusive access to observe or document in situ underwater cultural heritage shall be encouraged to create public awareness, appreciation, and protection of the heritage except where such access is incompatible with its protection and management.

11. No act or activity undertaken on the basis of this Convention shall constitute grounds for claiming, contending or disputing any claim to national sovereignty or jurisdiction.

Article 3 – Relationship between this Convention and the United Nations Convention on the Law of the Sea

Nothing in this Convention shall prejudice the rights, jurisdiction and duties of States under international law, including the United Nations Convention on the Law of the Sea. This Convention shall be interpreted and applied in the context of and in a manner

consistent with international law, including the United Nations Convention on the Law of the Sea.

Article 4 – Relationship to law of salvage and law of finds

Any activity relating to underwater cultural heritage to which this Convention applies shall not be subject to the law of salvage or law of finds, unless it:

(a) is authorized by the competent authorities, and

(b) is in full conformity with this Convention, and

(c) ensures that any recovery of the underwater cultural heritage achieves its maximum protection.

Article 5 – Activities incidentally affecting underwater cultural heritage

Each State Party shall use the best practicable means at its disposal to prevent or mitigate any adverse effects that might arise from activities under its jurisdiction incidentally affecting underwater cultural heritage.

Article 6 – Bilateral, regional or other multilateral agreements

1. States Parties are encouraged to enter into bilateral, regional or other multilateral agreements or develop existing agreements, for the preservation of underwater cultural heritage. All such agreements shall be in full conformity with the provisions of this Convention and shall not dilute its universal character. States may, in such agreements, adopt rules and regulations which would ensure better protection of underwater cultural heritage than those adopted in this Convention.

2. The Parties to such bilateral, regional or other multilateral agreements may invite States with a verifiable link, especially a cultural, historical or archaeological link, to the underwater cultural heritage concerned to join such agreements.

3. This Convention shall not alter the rights and obligations of States Parties regarding the protection of sunken vessels, arising from other bilateral, regional or other multilateral agreements concluded before its adoption, and, in particular, those that are in conformity with the purposes of this Convention.

Article 7 – Underwater cultural heritage in internal waters, archipelagic waters and territorial sea

1. States Parties, in the exercise of their sovereignty, have the exclusive right to regulate and authorize activities directed at underwater cultural heritage in their internal waters, archipelagic waters and territorial sea.

2. Without prejudice to other international agreements and rules of international law regarding the protection of underwater cultural heritage, States Parties shall require that the Rules be applied to activities directed at underwater cultural heritage in their internal waters, archipelagic waters and territorial sea.

3. Within their archipelagic waters and territorial sea, in the exercise of their sovereignty and in recognition of general practice among States, States Parties, with a view to cooperating on the best methods of protecting State vessels and aircraft, should inform the flag State Party to this Convention and, if applicable, other States with a verifiable link, especially a cultural, historical or archaeological link, with respect to the discovery of such identifiable State vessels and aircraft.

Article 8 – Underwater cultural heritage in the contiguous zone

Without prejudice to and in addition to Articles 9 and 10, and in accordance with Article 303, paragraph 2, of the United Nations Convention on the Law of the Sea, States Parties may regulate and authorize activities directed at underwater cultural heritage within their contiguous zone. In so doing, they shall require that the Rules be applied.

Article 9 – Reporting and notification in the exclusive economic zone and on the continental shelf

1. All States Parties have a responsibility to protect underwater cultural heritage in the exclusive economic zone and on the continental shelf in conformity with this Convention.

Accordingly:

(a) a State Party shall require that when its national, or a vessel flying its flag, discovers or intends to

engage in activities directed at underwater cultural heritage located in its exclusive economic zone or on its continental shelf, the national or the master of the vessel shall report such discovery or activity to it;

(b) in the exclusive economic zone or on the continental shelf of another State Party:

(i) States Parties shall require the national or the master of the vessel to report such discovery or activity to them and to that other State Party;

(ii) alternatively, a State Party shall require the national or master of the vessel to report such discovery or activity to it and shall ensure the rapid and effective transmission of such reports to all other States Parties.

2. On depositing its instrument of ratification, acceptance, approval or accession, a State Party shall declare the manner in which reports will be transmitted under paragraph 1(b) of this Article.

3. A State Party shall notify the Director-General of discoveries or activities reported to it under paragraph 1 of this Article.

4. The Director-General shall promptly make available to all States Parties any information notified to him under paragraph 3 of this Article.

5. Any State Party may declare to the State Party in whose exclusive economic zone or on whose continental shelf the underwater cultural heritage is located its interest in being consulted on how to ensure the effective protection of that underwater cultural heritage. Such declaration shall be based on a verifiable link, especially a cultural, historical or archaeological link, to the underwater cultural heritage concerned.

Article 10 – Protection of underwater cultural heritage in the exclusive economic zone and on the continental shelf

1. No authorization shall be granted for an activity directed at underwater cultural heritage located in the exclusive economic zone or on the continental shelf except in conformity with the provisions of this Article.

2. A State Party in whose exclusive economic zone or on whose continental shelf underwater cultural heritage is located has the right to prohibit or authorize any activity directed at such heritage to prevent interference with its sovereign rights or jurisdiction as provided for by international law including the United Nations Convention on the Law of the Sea.

3. Where there is a discovery of underwater cultural heritage or it is intended that activity shall be directed at underwater cultural heritage in a State Party's exclusive economic zone or on its continental shelf, that State Party shall:

(a) consult all other States Parties which have declared an interest under Article 9, paragraph 5, on how best to protect the underwater cultural heritage;

(b) coordinate such consultations as "Coordinating State", unless it expressly declares that it does not wish to do so, in which case the States Parties which have declared an interest under Article 9, paragraph 5, shall appoint a Coordinating State.

4. Without prejudice to the duty of all States Parties to protect underwater cultural heritage by way of all practicable measures taken in accordance with international law to prevent immediate danger to the underwater cultural heritage, including looting, the Coordinating State may take all practicable measures, and/or issue any necessary authorizations in conformity with this Convention and, if necessary prior to consultations, to prevent any immediate danger to the underwater cultural heritage, whether arising from human activities or any other cause, including looting. In taking such measures assistance may be requested from other States Parties.

5. The Coordinating State:

(a) shall implement measures of protection which have been agreed by the consulting States, which include the Coordinating State, unless the consulting States, which include the Coordinating State, agree that another State Party shall implement those measures;

(b) shall issue all necessary authorizations for such agreed measures in conformity with the Rules, unless the consulting States, which include the Coordinating State, agree that another State Party shall issue those authorizations;

(c) may conduct any necessary preliminary research on the underwater cultural heritage and shall issue all necessary authorizations therefore, and shall promptly inform the Director-General of the results, who in turn will make such information promptly available to other States Parties.

6. In coordinating consultations, taking measures, conducting preliminary research and/or issuing authorizations pursuant to this Article, the Coordinating State shall act on behalf of the States Parties as a whole and not in its own interest. Any such action shall not in itself constitute a basis for the assertion of any preferential or jurisdictional rights not provided for in international law, including the United Nations Convention on the Law of the Sea.

7. Subject to the provisions of paragraphs 2 and 4 of this Article, no activity directed at State vessels and aircraft shall be conducted without the agreement of the flag State and the collaboration of the Coordinating State.

Article 11 – Reporting and notification in the Area

1. States Parties have a responsibility to protect underwater cultural heritage in the Area in conformity with this Convention and Article 149 of the United Nations Convention on the Law of the Sea. Accordingly when a national, or a vessel flying the flag of a State Party, discovers or intends to engage in activities directed at underwater cultural heritage located in the Area, that State Party shall require its national, or the master of the vessel, to report such discovery or activity to it.

2. States Parties shall notify the Director-General and the Secretary-General of the International Seabed Authority of such discoveries or activities reported to them.

3. The Director-General shall promptly make available to all States Parties any such information supplied by States Parties.

4. Any State Party may declare to the Director-General its interest in being consulted on how to ensure the effective protection of that underwater cultural heritage. Such declaration shall be based on a verifiable link to the underwater cultural heritage concerned, particular regard being paid to the preferential rights of States of cultural, historical or archaeological origin.

Article 12 – Protection of underwater cultural heritage in the Area

1. No authorization shall be granted for any activity directed at underwater cultural heritage located in the Area except in conformity with the provisions of this Article.

2. The Director-General shall invite all States Parties which have declared an interest under Article 11, paragraph 4, to consult on how best to protect the underwater cultural heritage, and to appoint a State Party to coordinate such consultations as the "Coordinating State". The Director-General shall also invite the International Seabed Authority to participate in such consultations.

3. All States Parties may take all practicable measures in conformity with this Convention, if necessary prior to consultations, to prevent any immediate danger to the underwater cultural heritage, whether arising from human activity or any other cause including looting.

4. The Coordinating State shall:

(a) implement measures of protection which have been agreed by the consulting States, which include the Coordinating State, unless the consulting States, which include the Coordinating State, agree that another State Party shall implement those measures; and

(b) issue all necessary authorizations for such agreed measures, in conformity with this Convention, unless the consulting States, which include the Coordinating State, agree that another State Party shall issue those authorizations.

5. The Coordinating State may conduct any necessary preliminary research on the underwater cultural heritage and shall issue all necessary authorizations therefor, and shall promptly inform the Director-General of the results, who in turn shall make such information available to other States Parties.

6. In coordinating consultations, taking measures, conducting preliminary research, and/or issuing authorizations pursuant to this Article, the Coordinating State shall act for the benefit of humanity as a whole, on behalf of all States Parties. Particular regard shall be paid to the preferential rights of States of cultural, historical or archaeological origin in respect of the underwater cultural heritage concerned.

7. No State Party shall undertake or authorize activities directed at State vessels and aircraft in the Area without the consent of the flag State.

Article 13 – Sovereign immunity

Warships and other government ships or military aircraft with sovereign immunity, operated for non-commercial purposes, undertaking their normal mode of operations, and not engaged in activities directed at underwater cultural heritage, shall not be obliged to report discoveries of underwater cultural heritage under Articles 9, 10, 11 and 12 of this Convention. However States Parties shall ensure, by the adoption of appropriate measures not impairing the operations or operational capabilities of their warships or other government ships or military aircraft with sovereign immunity operated for non-commercial purposes, that they comply, as far as is reasonable and practicable, with Articles 9, 10, 11 and 12 of this Convention.

Article 14 – Control of entry into the territory, dealing and possession

States Parties shall take measures to prevent the entry into their territory, the dealing in, or the possession of, underwater cultural heritage illicitly exported and/or recovered, where recovery was contrary to this Convention.

Article 15 – Non-use of areas under the jurisdiction of States Parties

States Parties shall take measures to prohibit the use of their territory, including their maritime ports, as well as artificial islands, installations and structures under their exclusive jurisdiction or control, in support of any activity directed at underwater cultural heritage which is not in conformity with this Convention.

Article 16 – Measures relating to nationals and vessels

States Parties shall take all practicable measures to ensure that their nationals and vessels flying their flag do not engage in any activity directed at underwater cultural heritage in a manner not in conformity with this Convention.

Article 17 – Sanctions

1. Each State Party shall impose sanctions for violations of measures it has taken to implement this Convention.

2. Sanctions applicable in respect of violations shall be adequate in severity to be effective in securing compliance with this Convention and to discourage violations wherever they occur and shall deprive offenders of the benefit deriving from their illegal activities.

3. States Parties shall cooperate to ensure enforcement of sanctions imposed under this Article.

Article 18 – Seizure and disposition of underwater cultural heritage

1. Each State Party shall take measures providing for the seizure of underwater cultural heritage in its territory that has been recovered in a manner not in conformity with this Convention.

2. Each State Party shall record, protect and take all reasonable measures to stabilize underwater cultural heritage seized under this Convention.

3. Each State Party shall notify the Director-General and any other State with a verifiable link, especially a cultural, historical or archaeological link, to the underwater cultural heritage concerned of any seizure of underwater cultural heritage that it has made under this Convention.

4. A State Party which has seized underwater cultural heritage shall ensure that its disposition be for the public benefit, taking into account the need for conservation and research; the need for reassembly of a dispersed collection; the need for public access, exhibition and education; and the interests of any State with a verifiable link, especially a cultural, historical or archaeological link, in respect of the underwater cultural heritage concerned.

Article 19 – Cooperation and information-sharing

1. States Parties shall cooperate and assist each other in the protection and management of underwater cultural heritage under this Convention, including, where practicable, collaborating in the investigation, excavation, documentation, conservation, study and presentation of such heritage.

2. To the extent compatible with the purposes of this Convention, each State Party undertakes to share information with other States Parties concerning underwater cultural heritage, including discovery of heritage, location of heritage, heritage excavated or recovered contrary to this Convention or otherwise in violation of international law, pertinent scientific methodology and technology, and legal developments relating to such heritage.

3. Information shared between States Parties, or between UNESCO and States Parties, regarding the discovery or location of underwater cultural heritage shall, to the extent compatible with their national legislation, be kept confidential and reserved to competent authorities of States Parties as long as the disclosure of such information might endanger or otherwise put at risk the preservation of such underwater cultural heritage.

4. Each State Party shall take all practicable measures to disseminate information, including where feasible

through appropriate international databases, about underwater cultural heritage excavated or recovered contrary to this Convention or otherwise in violation of international law.

Article 20 – Public awareness

Each State Party shall take all practicable measures to raise public awareness regarding the value and significance of underwater cultural heritage and the importance of protecting it under this Convention.

Article 21 – Training in underwater archaeology

States Parties shall cooperate in the provision of training in underwater archaeology, in techniques for the conservation of underwater cultural heritage and, on agreed terms, in the transfer of technology relating to underwater cultural heritage.

Article 22 – Competent authorities

1. In order to ensure the proper implementation of this Convention, States Parties shall establish competent authorities or reinforce the existing ones where appropriate, with the aim of providing for the establishment, maintenance and updating of an inventory of underwater cultural heritage, the effective protection, conservation, presentation and management of underwater cultural heritage, as well as research and education.

2. States Parties shall communicate to the Director-General the names and addresses of their competent authorities relating to underwater cultural heritage.

Article 23 – Meetings of States Parties

1. The Director-General shall convene a Meeting of States Parties within one year of the entry into force of this Convention and thereafter at least once every two years. At the request of a majority of States Parties, the Director-General shall convene an Extraordinary Meeting of States Parties.

2. The Meeting of States Parties shall decide on its functions and responsibilities.

3. The Meeting of States Parties shall adopt its own Rules of Procedure.

4. The Meeting of States Parties may establish a Scientific and Technical Advisory Body composed of experts nominated by the States Parties with due regard to the principle of equitable geographical distribution and the desirability of a gender balance.

5. The Scientific and Technical Advisory Body shall appropriately assist the Meeting of States Parties in questions of a scientific or technical nature regarding the implementation of the Rules.

Article 24 – Secretariat for this Convention

1. The Director-General shall be responsible for the functions of the Secretariat for this Convention.

2. The duties of the Secretariat shall include:

(a) organizing Meetings of States Parties as provided for in Article 23, paragraph 1; and

(b) assisting States Parties in implementing the decisions of the Meetings of States Parties.

Article 25 – Peaceful settlement of disputes

1. Any dispute between two or more States Parties concerning the interpretation or application of this Convention shall be subject to negotiations in good faith or other peaceful means of settlement of their own choice.

2. If those negotiations do not settle the dispute within a reasonable period of time, it may be submitted to UNESCO for mediation, by agreement between the States Parties concerned.

3. If mediation is not undertaken or if there is no settlement by mediation, the provisions relating to the settlement of disputes set out in Part XV of the United Nations Convention on the Law of the Sea apply mutatis mutandis to any dispute between States Parties to this Convention concerning the interpretation or application of this Convention, whether or not they are also Parties to the United Nations Convention on the Law of the Sea.

4. Any procedure chosen by a State Party to this Convention and to the United Nations Convention on the Law of the Sea pursuant to Article 287 of the latter shall apply to the settlement of disputes under

this Article, unless that State Party, when ratifying, accepting, approving or acceding to this Convention, or at any time thereafter, chooses another procedure pursuant to Article 287 for the purpose of the settlement of disputes arising out of this Convention.

5. A State Party to this Convention which is not a Party to the United Nations Convention on the Law of the Sea, when ratifying, accepting, approving or acceding to this Convention or at any time thereafter shall be free to choose, by means of a written declaration, one or more of the means set out in Article 287, paragraph 1, of the United Nations Convention on the Law of the Sea for the purpose of settlement of disputes under this Article. Article 287 shall apply to such a declaration, as well as to any dispute to which such State is party, which is not covered by a declaration in force. For the purpose of conciliation and arbitration, in accordance with Annexes V and VII of the United Nations Convention on the Law of the Sea, such State shall be entitled to nominate conciliators and arbitrators to be included in the lists referred to in Annex V, Article 2, and Annex VII, Article 2, for the settlement of disputes arising out of this Convention.

Article 26 – Ratification, acceptance, approval or accession

1. This Convention shall be subject to ratification, acceptance or approval by Member States of UNESCO.

2. This Convention shall be subject to accession:

(a) by States that are not members of UNESCO but are members of the United Nations or of a specialized agency within the United Nations system or of the International Atomic Energy Agency, as well as by States Parties to the Statute of the International Court of Justice and any other State invited to accede to this Convention by the General Conference of UNESCO;

(b) by territories which enjoy full internal self-government, recognized as such by the United Nations, but have not attained full independence in accordance with General Assembly resolution 1514 (XV) and which have competence over the matters governed by this Convention, including the competence to enter into treaties in respect of those matters.

3. The instruments of ratification, acceptance, approval or accession shall be deposited with the Director-General.

Article 27 – Entry into force

This Convention shall enter into force three months after the date of the deposit of the twentieth instrument referred to in Article 26, but solely with respect to the twenty States or territories that have so deposited their instruments. It shall enter into force for each other State or territory three months after the date on which that State or territory has deposited its instrument.

Article 28 – Declaration as to inland waters

When ratifying, accepting, approving or acceding to this Convention or at any time thereafter, any State or territory may declare that the Rules shall apply to inland waters not of a maritime character.

Article 29 – Limitations to geographical scope

At the time of ratifying, accepting, approving or acceding to this Convention, a State or territory may make a declaration to the depositary that this Convention shall not be applicable to specific parts of its territory, internal waters, archipelagic waters or territorial sea, and shall identify therein the reasons for such declaration. Such State shall, to the extent practicable and as quickly as possible, promote conditions under which this Convention will apply to the areas specified in its declaration, and to that end shall also withdraw its declaration in whole or in part as soon as that has been achieved.

Article 30 – Reservations

With the exception of Article 29, no reservations may be made to this Convention.

Article 31 – Amendments

1. A State Party may, by written communication addressed to the Director-General, propose amendments to this Convention. The Director-General shall circulate such communication to all States Parties. If, within six months from the date of the circulation of the communication, not less than one half of the States Parties reply favourably to the request, the Director-General shall present such

proposal to the next Meeting of States Parties for discussion and possible adoption.

2. Amendments shall be adopted by a two-thirds majority of States Parties present and voting.

3. Once adopted, amendments to this Convention shall be subject to ratification, acceptance, approval or accession by the States Parties.

4. Amendments shall enter into force, but solely with respect to the States Parties that have ratified, accepted, approved or acceded to them, three months after the deposit of the instruments referred to in paragraph 3 of this Article by two thirds of the States Parties. Thereafter, for each State or territory that ratifies, accepts, approves or accedes to it, the amendment shall enter into force three months after the date of deposit by that Party of its instrument of ratification, acceptance, approval or accession.

5. A State or territory which becomes a Party to this Convention after the entry into force of amendments in conformity with paragraph 4 of this Article shall, failing an expression of different intention by that State or territory, be considered:

(a) as a Party to this Convention as so amended; and

(b) as a Party to the unamended Convention in relation to any State Party not bound by the amendment.

Article 32 – Denunciation

1. A State Party may, by written notification addressed to the Director-General, denounce this Convention.

2. The denunciation shall take effect twelve months after the date of receipt of the notification, unless the notification specifies a later date.

3. The denunciation shall not in any way affect the duty of any State Party to fulfil any obligation embodied in this Convention to which it would be subject under international law independently of this Convention.

Article 33 – The Rules

The Rules annexed to this Convention form an integral part of it and, unless expressly provided otherwise, a reference to this Convention includes a reference to the Rules.

Article 34 – Registration with the United Nations

In conformity with Article 102 of the Charter of the United Nations, this Convention shall be registered with the Secretariat of the United Nations at the request of the Director-General.

Article 35 – Authoritative texts

This Convention has been drawn up in Arabic, Chinese, English, French, Russian and Spanish, the six texts being equally authoritative.

Annex

Rules concerning activities directed at underwater cultural heritage

I. General principles

Rule 1. The protection of underwater cultural heritage through in situ preservation shall be considered as the first option. Accordingly, activities directed at underwater cultural heritage shall be authorized in a manner consistent with the protection of that heritage, and subject to that requirement may be authorized for the purpose of making a significant contribution to protection or knowledge or enhancement of underwater cultural heritage.

Rule 2. The commercial exploitation of underwater cultural heritage for trade or speculation or its irretrievable dispersal is fundamentally incompatible with the protection and proper management of underwater cultural heritage. Underwater cultural heritage shall not be traded, sold, bought or bartered as commercial goods.

This Rule cannot be interpreted as preventing:

(a) the provision of professional archaeological services or necessary services incidental thereto whose nature and purpose are in full conformity with this Convention and are subject to the authorization of the competent authorities;

(b) the deposition of underwater cultural heritage, recovered in the course of a research project in conformity with this Convention, provided such deposition does not prejudice the scientific or cultural interest or integrity of the recovered material or result in its irretrievable dispersal; is in accordance with the provisions of Rules 33 and 34; and is subject to the authorization of the competent authorities.

Rule 3. Activities directed at underwater cultural heritage shall not adversely affect the underwater

cultural heritage more than is necessary for the objectives of the project.

Rule 4. Activities directed at underwater cultural heritage must use nondestructive techniques and survey methods in preference to recovery of objects. If excavation or recovery is necessary for the purpose of scientific studies or for the ultimate protection of the underwater cultural heritage, the methods and techniques used must be as non-destructive as possible and contribute to the preservation of the remains.

Rule 5. Activities directed at underwater cultural heritage shall avoid the unnecessary disturbance of human remains or venerated sites.

Rule 6. Activities directed at underwater cultural heritage shall be strictly regulated to ensure proper recording of cultural, historical and archaeological information.

Rule 7. Public access to in situ underwater cultural heritage shall be promoted, except where such access is incompatible with protection and management.

Rule 8. International cooperation in the conduct of activities directed at underwater cultural heritage shall be encouraged in order to further the effective exchange or use of archaeologists and other relevant professionals.

II. Project design

Rule 9. Prior to any activity directed at underwater cultural heritage, a project design for the activity shall be developed and submitted to the competent authorities for authorization and appropriate peer review.

Rule 10. The project design shall include:

(a) an evaluation of previous or preliminary studies;

(b) the project statement and objectives;

(c) the methodology to be used and the techniques to be employed;

(d) the anticipated funding;

(e) an expected timetable for completion of the project;

(f) the composition of the team and the qualifications, responsibilities and experience of each team member;

(g) plans for post-fieldwork analysis and other activities;

(h) a conservation programme for artefacts and the site in close cooperation with the competent authorities;

(i) a site management and maintenance policy for the whole duration of the project;

(j) a documentation programme;

(k) a safety policy;

(l) an environmental policy;

(m) arrangements for collaboration with museums and other institutions, in particular scientific institutions;

(n) report preparation;

(o) deposition of archives, including underwater cultural heritage removed; and

(p) a programme for publication.

Rule 11. Activities directed at underwater cultural heritage shall be carried out in accordance with the project design approved by the competent authorities.

Rule 12. Where unexpected discoveries are made or circumstances change, the project design shall be reviewed and amended with the approval of the competent authorities.

Rule 13. In cases of urgency or chance discoveries, activities directed at the underwater cultural heritage, including conservation measures or activities for a period of short duration, in particular site stabilization, may be authorized in the absence of a project design in order to protect the underwater cultural heritage.

III. Preliminary work

Rule 14. The preliminary work referred to in Rule 10 (a) shall include an assessment that evaluates the significance and vulnerability of the underwater cultural heritage and the surrounding natural environment to damage by the proposed project, and the potential to obtain data that would meet the project objectives.

Rule 15. The assessment shall also include background studies of available historical and archaeological evidence, the archaeological and environmental characteristics of the site, and the consequences of any potential intrusion for the long-term stability of the underwater cultural heritage affected by the activities.

IV. Project objective, methodology and techniques

Rule 16. The methodology shall comply with the project objectives, and the techniques employed shall be as non-intrusive as possible.

V. Funding

Rule 17. Except in cases of emergency to protect underwater cultural heritage, an adequate funding base shall be assured in advance of any activity,

sufficient to complete all stages of the project design, including conservation, documentation and curation of recovered artefacts, and report preparation and dissemination.

Rule 18. The project design shall demonstrate an ability, such as by securing a bond, to fund the project through to completion.

Rule 19. The project design shall include a contingency plan that will ensure conservation of underwater cultural heritage and supporting documentation in the event of any interruption of anticipated funding.

VI. Project duration – timetable

Rule 20. An adequate timetable shall be developed to assure in advance of any activity directed at underwater cultural heritage the completion of all stages of the project design, including conservation, documentation and curation of recovered underwater cultural heritage, as well as report preparation and dissemination.

Rule 21. The project design shall include a contingency plan that will ensure conservation of underwater cultural heritage and supporting documentation in the event of any interruption or termination of the project.

VII. Competence and qualifications

Rule 22. Activities directed at underwater cultural heritage shall only be undertaken under the direction and control of, and in the regular presence of, a qualified underwater archaeologist with scientific competence appropriate to the project.

Rule 23. All persons on the project team shall be qualified and have demonstrated competence appropriate to their roles in the project.

VIII. Conservation and site management

Rule 24. The conservation programme shall provide for the treatment of the archaeological remains during the activities directed at underwater cultural heritage, during transit and in the long term. Conservation shall be carried out in accordance with current professional standards.

Rule 25. The site management programme shall provide for the protection and management in situ of underwater cultural heritage, in the course of and upon termination of fieldwork. The programme shall include public information, reasonable provision for site stabilization, monitoring, and protection against interference.

IX. Documentation

Rule 26. The documentation programme shall set out thorough documentation including a progress report of activities directed at underwater cultural heritage, in accordance with current professional standards of archaeological documentation.

Rule 27. Documentation shall include, at a minimum, a comprehensive record of the site, including the provenance of underwater cultural heritage moved or removed in the course of the activities directed at underwater cultural heritage, field notes, plans, drawings, sections, and photographs or recording in other media.

X. Safety

Rule 28. A safety policy shall be prepared that is adequate to ensure the safety and health of the project team and third parties and that is in conformity with any applicable statutory and professional requirements.

XI. Environment

Rule 29. An environmental policy shall be prepared that is adequate to ensure that the seabed and marine life are not unduly disturbed.

XII. Reporting

Rule 30. Interim and final reports shall be made available according to the timetable set out in the project design, and deposited in relevant public records.

Rule 31. Reports shall include:

(a) an account of the objectives;

(b) an account of the methods and techniques employed;

(c) an account of the results achieved;

(d) basic graphic and photographic documentation on all phases of the activity;

(e) recommendations concerning conservation and curation of the site and of any underwater cultural heritage removed; and

(f) recommendations for future activities.

XIII. Curation of project archives

Rule 32. Arrangements for curation of the project archives shall be agreed to before any activity commences, and shall be set out in the project design.

Rule 33. The project archives, including any underwater cultural heritage removedand a copy of all supporting documentation shall, as far as possible, be kept togetherand intact as a collection in a manner that is available for professional and public access as well as for the curation of the archives. This should be done as rapidly as possible and in any case not later than ten years from the completion of the project, in so far as may be compatible with conservation of the underwater cultural heritage.

Rule 34. The project archives shall be managed according to international professional standards, and subject to the authorization of the competent authorities.

XIV. Dissemination

Rule 35. Projects shall provide for public education and popular presentation of the project results where appropriate.

Rule 36. A final synthesis of a project shall be:

(a) made public as soon as possible, having regard to the complexity of the project and the confidential or sensitive nature of the information; and

(b) deposited in relevant public records.



Photo Credit: Early Bronze Age Ovoid banded amphora being excavated off the coast of Kekova Island, Turkey, image: Hakan Oniz.

AXA SİGORTA

Climate change is reshaping coastlines and seas. Its impacts extend beyond the natural environment, reaching the places, knowledge, and collective memory through which communities make sense of their past and imagine their futures.

AXA Foresight Report 2026: Atlas of New Futures reminds us that global changes do not affect every part of the world in the same way. Each region experiences this transformation according to its own circumstances, experiences, and needs. Understanding local realities, anticipating potential risks, and developing solutions that support adaptation to change are therefore of vital importance.

Coastal and underwater cultural heritage is an important part of this transformation. To protect this heritage, we must first make the threats it faces more visible, bring experts from different disciplines together on common ground, and listen to the knowledge and experiences of the communities connected to these places. Only in this way can we carry our shared past into the future.

As AXA Türkiye, we are pleased to support the publication of this book and to contribute to making the knowledge and expertise it contains accessible to a wider audience.

Yavuz Ölken
AXA Türkiye CEO