ADAPT
NORTHERN HERITAGE
CONFERENCE
05 & 06 MAY 2020

Adapting historic places to climate change

Proceedings of the international virtual conference of the project Adapt Northern Heritage

Northern Periphery and Arctic Programme
2014–2020

EUROPEAN UNION
Investing in your future
European Regional Development Fund

Acknowledgements

The conference was run by the Project Partners of the project Adapt Northern Heritage (2017-2020), namely Historic Environment Scotland, Minjastofnun Íslands, Norsk institutt for kulturminneforskning and Riksantikvaren, for which they received funding from the European Union, Iceland and Norway through the Interreg Programme for the Northern Periphery and Arctic.

The Project Partners wish to extend their sincere thanks to the individuals and organisations that contributed their time and expertise in reviewing submissions. Further, a special thanks to all speakers, chairs and facilitators involved.

Editors

Gemma Houston, Vanessa Glindmeier, Carsten Hermann (Historic Environment Scotland)

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Cover image

The monastery of the Solovetsky Islands in Russia's White Sea is a northern UNESCO World Heritage site and a case study in the project Adapt Northern Heritage. The archipelago features in three of the papers / presentations of the conference.

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1 PREFACE

The Adapt Northern Heritage virtual conference brought the international project of the same name to a close. Funded by the Interreg Programme for the Northern Periphery and Arctic, the project Adapt Northern Heritage (2017-2020) has supported northern communities to adapt their cultural heritage to the environmental impacts of climate change and associated natural hazards. Over three years, Historic Environment Scotland, Minjastofnun Íslands, Norsk institutt for kulturminneforskning and Riksantikvaren have explored climate change impacts at nine case study sites with numerous stakeholders and how we can start discussions about adaptation planning – or sometimes managing the loss of a historic place, often at the heart of a community.

In the project, the four project partners have developed the *Adapt Northern Heritage toolkit* which helps communities and conservation professionals alike, to explore the different steps involved in such a risk management process. Holding a conference, originally planned to take place in the World Heritage site of Edinburgh, Scotland, was meant to be an opportunity to present the project's tools to a wider professional and scholarly audience. Much of the project, however, focussed on engaging with stakeholders of various kinds, including national public bodies, universities, conservation organisations and indigenous communities. In that spirit, it seemed logical to us partners that this project conference needed to be about more than just our project results. Engaging with colleagues working in the field of historic environment conservation and reaching out to those caring for northern historic places was critical, hearing each other's stories and learning from each other's experiences mutually beneficial. The conference was too good an opportunity for this to be missed.

With 35 speakers from 11 countries, including keynote lectures from Europa Nostra and the UNESCO World Heritage Centre, the conference brought together practitioners and scholars concerned with the often-dramatic impacts of climate change on outstandingly beautiful and culturally significant historic places and finding ways to cope with this change either by adapting these places or accepting and managing their loss longer term. The conference featured ten dedicated sessions and three special foci themes: cultural heritage in the Arctic and sub-Arctic, cultural heritage of northern indigenous communities and northern UNESCO World Heritage.

The Covid-19 pandemic meant that the conference was to become an exercise in practicing *adaptation planning* for us organisers. Within two months, what was initially planned as a real-world event, was transferred into a fully digital, freely accessible format. I would like to especially thank all our speakers for supporting this transition. We've lost not even one on the move! Thank you also to the numerous session chairs, peer reviewers, keynote lecturers, behind-the-scenes moderators and members of the discussion panel. I would also like to extent my thanks to our IT support, GloCast, who have patiently guided us through our first virtual conference experience and have lend their expertise to everyone involved along the way. I am also immensely grateful for the constant support from my project partners and conference organisers Rebecca Bain, Marte Boro, Vanessa Glindmeier, Annika Haugen, Guðmundur Stefán Sigurðarson and Gemma Houston.

And, finally, neither this conference nor the associated project would have been possible without the financial support of the European Union, Iceland and Norway, through the Interreg Programme for the Northern Periphery and Arctic. Thank you for that vital support!

Carsten Hermann

Edinburgh, 25 May 2020

2 COMMITTEES

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Committee chairs

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Carsten Hermann, Historic Environment Scotland, Scotland

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Chris Archer, *GloCast, Scotland*

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Rebecca Bain, *Historic Environment Scotland, Scotland*

Rikki Mohi, *Historic Environment Scotland, Scotland*

3 PROGRAMME

Conference day 1 – Tuesday, 5th May 2020

Session 1 – Welcome & keynotes

09:30 – 10:45 British Summer Time
Chair: Ewan Hyslop, Historic Environment Scotland, Scotland

09:30 – 09:40
Introduction to conference by session chair

09:40 – 09:50
Welcome
Alex Paterson, Historic Environment Scotland, Scotland

09:50 – 10:00
Welcome
Frank Ross, The Right Honourable Lord Provost of City of Edinburgh, Scotland

10:00 – 10:30
Engagement of northern indigenous communities in World Heritage Site management
Isabelle Anatole-Gabriel, Chief of Unit, Europa and North America Unit, UNESCO World Heritage Centre, Sector for Culture

WORLD HERITAGE | ARCTIC & SUBARCTIC

10:30 – 10:45
Q&A

Conference day 1 – Tuesday, 5th May 2020

Session 2 – The Adapt Northern Heritage Project

11:00 – 12:15 British Summer Time
Chair: Rebecca Jones, Historic Environment Scotland, Scotland

11:00 – 11:20
Interreg NPA project Adapt Northern Heritage
Carsten Hermann, Historic Environment Scotland, Scotland

ADAPT NORTHERN HERITAGE

11:20 – 11:40
Risk assessments and adaptation planning
Marte Boro, Riksantikvaren, Norway

ADAPT NORTHERN HERITAGE

11:40 – 12:00
Project case studies from across northern world regions
Annika Haugen, Norsk institutt for kulturminneforskning, Norway

WORLD HERITAGE
ARCTIC & SUBARCTIC
ADAPT NORTHERN HERITAGE
INDIGENOUS

12:00 – 12:15
Q&A

Conference day 1 – Tuesday, 5th May 2020

Session 3 – Adapting historic buildings

13:30 – 14:45 British Summer Time
Chair: Carl Carrington, Blackpool Council, England

13:30 – 13:50
Climate change impacts on cultural and historic ensemble of the Solovetsky Islands
Dr. Maria Frolova, Northern (Arctic) Federal University, Russia

WORLD HERITAGE | ARCTIC & SUBARCTIC

13:50 – 14:10
Traditional buildings health check: a new approach to built heritage in Scotland
Ali Davey, Stirling City Heritage Trust / Historic Environment Scotland, Scotland

14:10 – 14:30
Managing the World Heritage site Røros Mining Town and the Circumference
Magnus Borgos, Røros Kommune, Norway

WORLD HERITAGE

14:30 – 14:45
Q&A

Conference day 1 – Tuesday, 5th May 2020

Session 4 - Building retrofit and fabric assessments

13:30 – 14:45 British Summer Time
Chair: Carsten Hermann, Historic Environment Scotland, Scotland

13:30 – 13:50
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Lingjun Hao, Eurac Research, Italy

13:50 – 14:10
Hygrothermal performance of an old building with log walls from the region of Vestfold in Norway
Petros Choidis, Oslo Metropolitan University, Norway

14:10 – 14:30
Energy Pathfinder: Approaching near zero energy in historic buildings
Kevin McCartney, University College Cork, Ireland

14:30 – 14:45
Q&A

Conference day 1 – Tuesday, 5th May 2020

Session 5 – Developing guidance for conservation practice

15:00 – 16:35 British Summer Time
Chair: Kirstine Møller, Memorial University of Newfoundland, Ilisimatusarfik - University of Greenland, Greenland

15:00 – 15:20
Conservation strategies for archaeological excavated structures in an environment change future
Gavin Douglas, Historic Environment Scotland, Scotland

15:20 – 15:40
Think globally, act locally. Checklist for safeguarding cultural heritage interior from climate hazards
Nina Kjølsen Jernæs, Norsk institutt for kulturminneforskning, Norway

15:40 – 16:00
How can conservation management plans for cultural heritage be used as a tool for climate adaption?
Camilla Altahr-Cederberg & Helen Simonsson, Riksantikvarieämbetet, Sweden

16:00 – 16:20
Two nations, one approach: Establishing joint-nation coastal and maritime baseline data for future resilience planning; the CHERISH Project
Dr. Toby Driver, Royal Commission on the Ancient and Historical Monuments of Wales, Wales

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Conference day 1 – Tuesday, 5th May 2020

Session 6 – Maritime cultural heritage in a changing climate

15:00 – 16:35 British Summer Time

Chair: Philip Robertson, Historic Environment Scotland, Scotland

15:00 – 15:20

CHERISH: Climate change impacts on a maritime cultural landscape, Ballinskelligs Bay, County Kerry

Sandra Henry, Discovery Programme, Ireland

15:20 – 15:40

Greenland's wild west: Cruise ships, climate change and threats to heritage sites

Hans H. Harmsen, Greenland National Museum and Archives / National Museum of Denmark, Greenland

ARCTIC & SUBARCTIC | WORLD HERITAGE | INDIGENOUS

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The effects of climate change on coastal heritage sites located on the south-west coast of Ireland

Fergus McCormick, Office of Public Works, Ireland

16:00 – 16:20

A Climate Vulnerability Index for World Heritage: Assessing climate change risks at the Heart of Neolithic Orkney

Alice Lyall, Historic Environment Scotland

WORLD HERITAGE

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Q&A

Conference day 2 – Wednesday, 6th May 2020

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Chair: Guðmundur Stefán Sigurðarson, Minjastofnun Íslands, Iceland

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Environmental impact of wind turbines on the Solovetsky Islands
Pavel Maryandyshev, Northern (Arctic) Federal University, Russia

WORLD HERITAGE | ARCTIC & SUBARCTIC

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Grave Concerns: How burial traditions increase climate risk at medieval Irish church sites
Dr. Michael Connolly, Kerry County Council, Ireland

11:05 – 11:25
Saving the Lodberries of Shetland
Monica Warwick, Historic Environment Scotland, Scotland

11:25 – 11:45
Bartjan – climate change and the effects on Sámi cultural heritage sites
Jerker Bexelius, Stiftelsen Gaaltje, Sweden

INDIGENOUS

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Q&A

Conference day 2 – Wednesday, 6th May 2020

Session 8 – Managing loss

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Chair: Cathy Daly, University of Lincoln, England

10:25 – 10:45
An assessment of the impact of coastal erosion on the availability of marram grass for thatching on Tiree
Kim de Buiteleir, Argyll & Bute Council, Scotland

10:45 – 11:05
Adaptation and relocation of built heritage: what can we learn from the urban transformations of Swedish mining towns?
Andrea Luciani & Jennie Sjöholm, Luleå University of Technology, Sweden

ARCTIC & SUBARCTIC

11:05 – 11:25
Museums and community engagement of sites at risk through virtual reality
Alan Miller, University of St. Andrews, Scotland

11:25 – 11:45
Dunbeg Promontory Fort and Medieval Settlement site, Co. Kerry: the archaeological management of retreat and loss
Connie Kelleher, Department of Culture, Heritage and the Gaeltacht, Ireland

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Q&A

Conference day 2 – Wednesday, 6th May 2020

Session 9 – Urban assessment

13:00 – 14:15 British Summer Time
Chair: Tor Broström, Uppsala University, Sweden

13:00 – 13:20
Specification of the planning process of adaptation urban areas with historic objects to climate change
Eva Streberova, Chief Architect's Office, Slovak Republic

13:20 – 13:40
HYPERION - A decision support system for improved resilience and sustainable reconstruction of historic areas
Antonis Kalis, I-SENSE Group, Greece

13:40 – 14:00
Data-driven and community-based resilience improvement of historic areas: SHELTER project
Aitziber Egusquiza, Tecnalia, Spain

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Q&A

Conference day 2 – Wednesday, 6th May 2020

Session 10 - Panel discussion and concluding keynote

14:30 – 16:30 British Summer Time
Chair: Carsten Hermann, Historic Environment Scotland, Scotland

14:30 – 15:00
'Meaning…what?' Re-evaluating cultural heritage in a post-COVID-19 world
Graham Bell, Europa Nostra, England

15:00 – 15:15
Q&A

15:15 – 15:45
Conference reflections
Mairi Davies, Historic Environment Scotland, Scotland

15:45 – 16:15
Panel discussion

16:15 – 16:30
Forward look and vote of thanks
Carsten Hermann, Historic Environment Scotland, Scotland

4 FOCUS THEMES

ARCTIC & SUBARCTIC

Arctic & Subarctic cultural heritage

Climate change in the Arctic and Subarctic regions is particularly pronounced with often dramatic consequences for historic places in these parts of the world. The extreme climatic conditions, geographic remoteness and population dispersedness of these areas are adding to the conservation challenges when caring for Arctic and Subarctic historic place.

INDIGENOUS

Cultural heritage of northern indigenous communities

Indigenous communities in northern world regions include the communities of the Sámi in Sápmi (in northern Scandinavia, Finland and Russia's Kola peninsula) the Inuit in northern North America (in Alaska, Canada and Greenland) and the Yupik (in Alaska and Russia's Far East). Western concepts of cultural heritage conservation often deviate from related cultural practices of indigenous communities, which often prioritise intangible cultural heritage over the tangible.

WORLD HERITAGE

Northern UNESCO World Heritage sites

Numerous UNESCO World Heritage site are located in the northern world, including the Arctic and Subarctic regions. Many of these sites are of extraordinary remoteness and vastness, making their management a particular challenge. The impacts of both climate change and human activity, for example in the form of natural resource extraction and tourism, often need careful management in order to retain the *outstanding universal value* of these sites.

ADAPT NORTHERN HERITAGE

Adapt Northern Heritage Project

Climate change in the Arctic and Subarctic regions is particularly pronounced with often dramatic consequences for historic places in these parts of the world. The extreme climatic conditions, geographic remoteness and population dispersedness of these areas is adding to the conservation challenges when caring for historic place in the Arctic and Subarctic.

5 CONFERENCE PAPERS

Session 1: Welcome and keynotes

Session chair

Ewan Hyslop, Historic Environment Scotland

Welcome addresses

Welcome

Alex Paterson, Historic Environment Scotland, Scotland

Welcome

Frank Ross, The Right Honourable Lord Provost of City of Edinburgh, Scotland

Keynote lectures

Engagement of northern indigenous communities in World Heritage Site management

Isabelle Anatole-Gabriel, Chief of Unit, Europa and North America Unit, UNESCO World Heritage Centre, Sector for Culture

Session 2: The Adapt Northern Heritage Project

Session chair

Rebecca Jones, Historic Environment Scotland, Scotland

Presentations

Interreg NPA project Adapt Northern Heritage

Carsten Hermann, Historic Environment Scotland, Scotland

Risk assessments and adaptation planning

Marte Boro, Riksantikvaren, Norway

Project case studies from across northern world regions

Annika Haugen, Norsk institutt for kulturminneforskning, Norway

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Managing the World Heritage site Røros Mining Town and the Circumference

Magnus Borgos, Røros Kommune, Norway

Climate Change Impacts on the Cultural and Historic Ensemble of the Solovetsky Islands

M. Frolova[1], A. Shinkaruk[1], Y. Sokolova[1]

[1]Department of Cultural Heritage Objects of the Northern and Arctic Territories, Northern (Arctic) Federal University named after M.V. Lomonosov (NArFU), Arkhangelsk, Russia. E-mail: m.aizenstadt@narfu.ru

Abstract

One of the most serious risks for the preservation of cultural heritage objects is climate change. That is why continuous climate monitoring, establishing the relationship between climate changes and the state of building structures, and identifying the main problem areas leading to the deterioration and subsequent loss of cultural heritage sites are important objectives. The UNESCO World Heritage Site "Cultural and Historic Ensemble of the Solovetsky Islands" was chosen as the subject of the study. Based on an analysis of climate change and the natural environment on the Solovetsky Islands, the trends and relationships were detected. The main climate indicators affecting architectural monuments are air temperature, amount of precipitation, relative humidity, as well as wind speed and direction. The nature and mechanism of climate change impacts on wood and stone structures were investigated. Based on the obtained data, recommendations for the sustainable management and adaptation of the historic site were developed to minimize the negative anthropogenic and natural impacts.

Keywords: climate change; cultural heritage; Solovetsky Islands; building structures; adaptation measures

1. Introduction

The dynamics of man-made processes as a result of increased human activity in the present context negatively affect the preservation of historical sites and require tracking risks of changes in the condition of the sites during their operation.

The protection and preservation of cultural heritage sites, including immovable historical and cultural monuments made of stone, has become a pressing issue in recent decades. For instance, unpredictable weather conditions, rising sea level, coastline erosion and destruction, and increased natural disasters are consequences of climate change. They are global in nature and unprecedented in scope [1]. It is known that brick and natural stone, such as limestone, marble, sandstone, dolomite, marl, tuffs, granite, basalt, and others, were widely used as building and finishing materials in the construction of architectural sites. Their durability can be measured in hundreds and thousands of years. Depending on the climatic zone of the structure, rock aging under the influence of natural moisture, frost, wind, insolation, biodegradants, and groundwater salts may occur at different rates. However, the rate of negative processes has increased significantly in the last century due to intensive human activity. The influence of anthropogenic factors on the conservation of stone structures has become comparable to the effects of natural disasters such as floods, sandstorms, and earthquakes [2-8].

Thus, climate change is one of the main contemporary challenges in the context of cultural heritage site preservation. In this regard, the relevance of developing an integrated system for the sustainable management of architectural monument preservation is obvious. In our opinion, an integrated preservation management system should consist of the following mandatory elements: 1) comprehensive monitoring of environmental factors (natural and man-made); 2) continuous monitoring of the current system state (wear and aging); 3) risk and threat assessment; forecast of changes in the physical condition of the site; 4) development of adaptation measures aimed to preserve the site and assessment of their effectiveness.

The goal of this study is to assess the impact of climate change on the integrity of the UNESCO World Heritage Site “Cultural and Historic Ensemble of the Solovetsky Islands”. To achieve this goal, we needed to accomplish the following tasks: 1) analyse climate data on Bolshoy Solovetsky Island and identify the main trends that indicate intensification of the climate change processes; 2) collect information / conduct research to study the technical condition of the Solovetsky Monastery elements; 3) draw a conclusion about the effect of global climatic processes on the integrity of the Solovetsky Monastery structures; 4) develop site preservation recommendations.

2. Methodology

The analysis of climate change and the natural environment on the Solovetsky Islands was conducted based on the indicators (average monthly and average annual air temperature; absolute maximum and minimum air temperature; monthly and annual precipitation; relative humidity; snow depth; wind speed and direction; hydrometeorological parameters of the White Sea; species composition and abundance of flora and fauna) using summary reports on the implementation of the Environmental Monitoring Program of the Solovetsky Archipelago in 2009–2017 [9]; climate data at weather station number 22429 in Solovetsky (point 65° 02' N, 35° 43' E; 7 m) [10]; and investigations of the White Sea area (64–68° N, 33–44° E), presented in articles [11, 12].

To establish the effect of global climatic processes on the state of the structures of the World Heritage Site “Cultural and Historic Ensemble of the Solovetsky Islands”, a number of elements of the monastery complex were taken as subjects of the study, namely: Korozhnaya Tower, Pryadilnaya Tower, and Belaya Tower. The choice of these structures for the study was determined by their location and spatial orientation, which establish a distinct pattern in the prevailing wind direction that is critical in assessing the effect of climatic parameters on the condition of the structural elements.

The procedure of inspecting the building structures, the conceptual flow chart, and the scope of work that enabled an unbiased condition assessment conform with the applicable regulations SP 13-102-2003, “Inspection rules for load-bearing structures of buildings and installations” [13–15]. The structural health data obtained were used to develop practical guidelines for correcting the detected defects and damage.

3. Results and Discussion

The analysis of average monthly air temperature during 2009–2018 showed that the cold period from November to March is characterized by a significant increase in temperature and a deviation from the long-term average value (norm). Due to the temperature rise in these and subsequent months, the duration of the warm period is increasing.

A positive linear trend was detected in the change of the average annual air temperature, which was 0.0162 °C (Figure 1). Thus, from 1888 to 2018, the air temperature increased on average by 2.1 °C and exceeded the long-term average value.

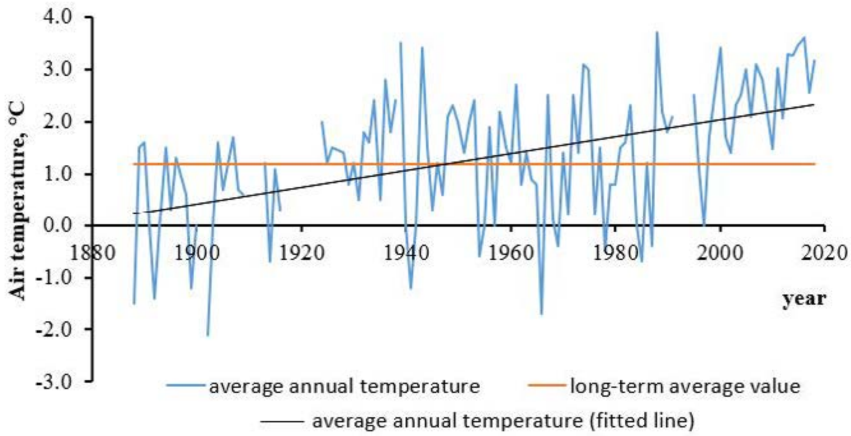

Figure 1. Variation of the average annual air temperature during 1888–2018

From 1891 to 2018, the total precipitation increased on average by 13 mm in the cold season and decreased on average by 10 mm in the warm season.

A positive linear trend was detected in the change of the average annual relative humidity (Figure 2), which was 0.1772%. Thus, from 2009 to 2018, the relative humidity increased on average by 10% and exceeded the long-term average value.

A positive linear trend was detected in the change of the average annual and maximum values of the snow depth (Figure 3). Thus, from 2009 to 2018, the average annual snow depth increased by 2 cm, and the maximum value of this parameter increased by 15 cm. The maximum snow depth (65 cm) was observed on 12 March 2013.

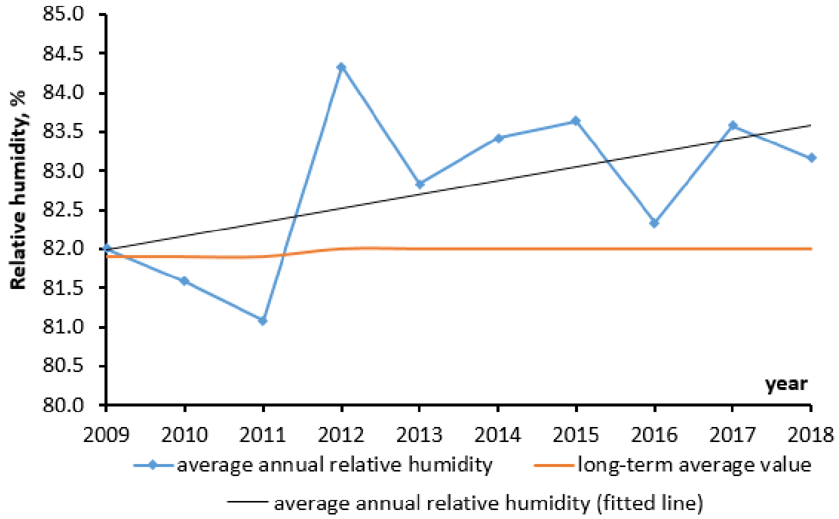

Figure 2. Variation of the average annual relative humidity during 2009–2018

For the 10-year period from 2009 to 2018, the wind direction gradually changed from north-east to south-west (Figures 4, 5). The number of windless days decreased by 8.1%.

Thus, based on the analysis of a sufficiently large body of data on the main climate indicators in the local territory of the Solovetsky Islands, we can conclude that climate transformation is taking place in this territory due to global processes of climate change on Earth.

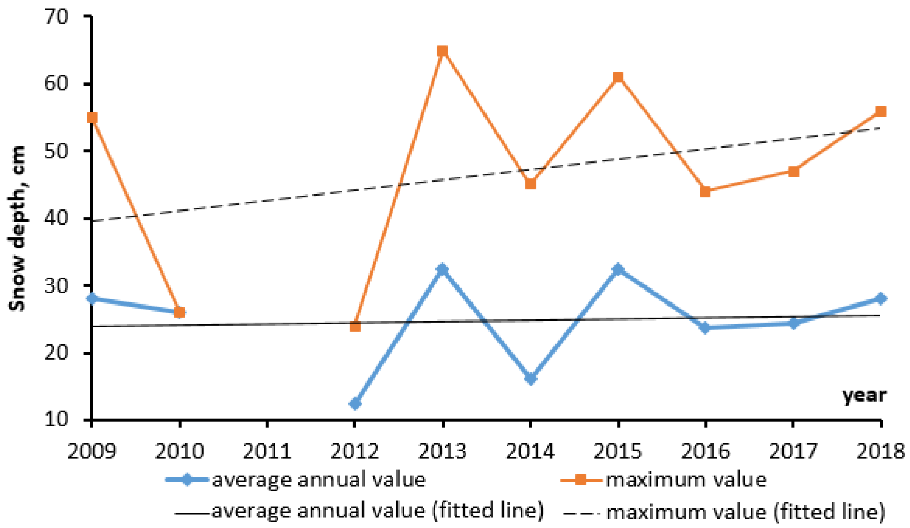

Figure 3. Variation of the average annual and maximum values of the snow depth during 2009–2018

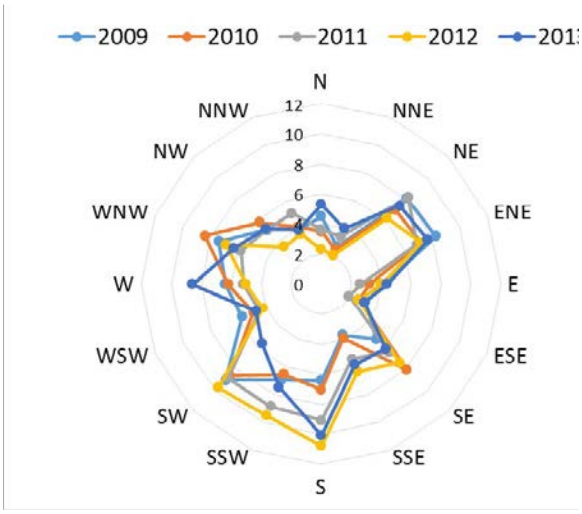

Figure 4. Prevailing wind directions during 2009–2013

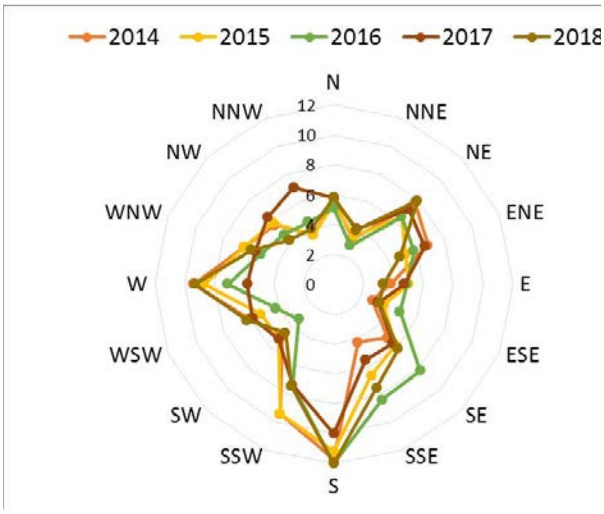

Figure 5. Prevailing wind directions during 2014–2018

The subjects of the study, Korozhnaya Tower, Pryadilnaya Tower, and Belaya Tower, are round structures with four tiers, located on hills. The walls of the towers are made of large boulders with the space between them filled with small boulders and lime mortar brickwork. The upper parts of the towers are made of bricks. The towers are in the shape of a truncated cone. The walls are up to 6 meters thick at the bases of the towers. The wall thickness decreases toward the top. The walls are 2 meters thick at the fourth tier. Each tier is fitted with loopholes along the perimeter of the structure. The lintels of the loopholes are made of flat boulders. The loophole bays are enclosed in brick archways. The floors between the tiers are wooden.

The nature of the detected defects and damage, and practical recommendations to correct them for the subjects of the study are presented in Table 1.

Table 1. Detected defects and practical recommendations to correct them

Element of the WH Site / Location	Nature of the detected defects and damage	Practical recommendations
Korozhnaya Tower / North-western part of the Solovetsky Monastery	- longitudinal and transverse cracks in the brick archways. The width of individual cracks is up to 24 mm; - spalled bricks; - wood-destroying fungi damage to the floor beams between the 2nd and 3rd tiers both in the bearings and in the spans.	1. It is necessary to seal the cracks in the brick masonry. 2. It is necessary to protect the wooden structures of the floors from biological damage by coating them with a wood preservative. The wood preservative should meet the following requirements: - highly toxic to fungi and insects, but safe for humans and animals; - does not degrade the aesthetic appearance or the physical and mechanical properties of wood; - does not corrode metal structures in contact with wood; - impregnates wood well and does not get washed out; - does not change its chemical composition; - does not have a strong smell; - includes a light blocking pigment that protects against moisture. 3. It is necessary to constantly monitor the structural condition of all elements of the Solovetsky Monastery.
Belaya Tower / Southern part of the Solovetsky Monastery	- the base of the tower is weakened; - longitudinal and transverse through cracks in the brick archways and exterior walls. The width of individual cracks is up to 30 mm; - spalled bricks; - plant growth in joints between boulders; - deflection of the brick archway enclosing the loophole of the 1st tier between sectors 2 and 3.	
Pryadilnaya Tower / South-western part of the Solovetsky Monastery	- longitudinal and transverse cracks in the brick archways. The existing cracks in the walls are not expanding; - biological damage to the floor beams of the 3rd and 4th tiers in the bearings. Cross-sectional loss of 50%; - excessive deflection of the self-supporting beam of the 4th tier.	

When comparing the climate data with the data from the technical inspection of the structures, it can be assumed that an increase in air temperature and humidity will intensify the deterioration processes of the brick masonry and the biodegradation of the wooden elements of these structures.

The observed magnification of the destructive effect of thermal and humidity deformations is associated with the nature of the ongoing climate changes (growth in the amount of liquid and mixed precipitation in the cold season, an increase in the number of freeze-thaw cycles, and increased wetting of building walls followed by freezing). The available observational data are not indicative of a noticeable increase in wind loads. However, if the average wind speeds remain constant or change slightly, their probability distributions may transform due to the increased influence of wind gusts. In this regard, additional regional studies are required.

4. Conclusion

Thus, due to an increase in extremely high air temperatures and an increase in precipitation, we can expect intensification of the combined effects of wind loads, thermal deformation, and corrosion failure. In this regard, the main adaptation measures for the preservation of the World Heritage Site are:

a. ongoing local monitoring of climate indicators in combination with regular technical inspections of the main structures of the Solovetsky Monastery;
b. conducting timely repair and restoration work in accordance with the regulatory requirements for World Heritage Sites;
c. creation of local expert groups engaged in the study of climate effects on the state of the structures of the Solovetsky Monastery;
d. engaging public organizations and other interested parties and informing them about the state of the structures and climate change impacts on them.

5. References

[1] IPCC, (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [online]. R. K. Pachauri, L. A. Meyer, eds. Geneva, Switzerland: IPCC. 151 p. [Viewed 23 April 2020]. Available from: https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf

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Traditional Buildings Health Check: changing behaviour around built heritage maintenance in Scotland

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Abstract

Scotland's climate is changing; increased rainfall and more frequent extreme weather is putting increased pressure on Scotland's traditional buildings. Poorly maintained buildings are less resilient to the effects of climate change. The 2010 Scottish House Condition Survey found that 76% of traditional (pre-1919) domestic buildings needed repairs to critical elements (components responsible for weather tightness and structural stability). There is currently no national strategy to address widespread poor building maintenance and the missed opportunities for small-scale adaptations that could be carried out as part of a routine maintenance schedule. In 2013, Historic Environment Scotland and the Construction Industry Training Board (Scotland) funded a 5-year pilot project, the Traditional Buildings Health Check*, as one possible means to adapt property owner behavior. The service supports property owners to proactively plan repair and maintenance. The pilot was delivered by Stirling City Heritage Trust and continues to be delivered as a core part of their operation.*

Keywords – Maintenance, repairs, traditional buildings, membership, skills, behaviour

1. Introduction

In 2013, Historic Environment Scotland and the Construction Industry Training Board (Scotland) funded a 5-year pilot project called the Traditional Buildings Health Check. The pilot aimed to change the behaviour of Scottish building owners by supporting them to take a more proactive approach to inspecting, maintaining and repairing their buildings. The pilot was designed and delivered by Stirling City Heritage Trust. The pilot aimed to test whether building owners would join the scheme, would it change their behaviour and what impact would that have on the local historic environment. Could this scheme be used as a model to change behaviour in other parts of Scotland and promote more proactive building maintenance?

2. Background

Scotland has approximately 455,000 traditionally constructed (generally pre-1919) dwellings; this accounts for roughly 20% of Scotland's total housing stock. It is estimated that 85% of existing traditional buildings will still be in use in 2050. There is increasing evidence of the deteriorating condition of Scotland's traditional buildings. The 2010 Scottish House Condition

Survey (SHCS) noted that 76% of traditional dwellings needed repairs to “critical elements” – components that keep a building wind and watertight and structurally sound. We know that disrepair not only reduces a building’s resilience to the effects of climate change, but directly affects the wellbeing of occupants, increases fuel poverty and poor energy efficiency and contributes to increased incidents of high-level masonry falls.

Scotland’s climate is changing – increased rainfall and wind-driven rain, increased wetting and drying cycles and more frequent extreme weather events are putting increasing pressure on the 76% of buildings that are already more vulnerable to the weather. There is currently no national strategy for dealing with essential repair and maintenance for traditional built fabric and critical opportunities to embed adaptation into routine repair and maintenance are being missed.

Figure 1. Many building owners ignore obvious signs of disrepair

Building owner behavior is a key contributing factor to high rates of disrepair. Many owners take a reactive approach to repairs; never thinking about or inspecting their buildings until problems arise. More serious repair issues, such as eroded chimney stacks or loose high-level masonry can go unnoticed for years as they are not easily visible or evident to building owners. Owners who do take a more proactive approach often lack the confidence and knowledge to commission the most appropriate repairs for their building and can be suspicious of contractor advice.

Problems associated with multiple ownership (such as traditional Scottish tenements) have also been a long-standing barrier to proactive maintenance, most notably in areas where engaging factors is not standard practice. Absentee landlords, a high rate of owner turnover and the added logistical complications of coordinating multiple (and sometimes uncooperative) owners frequently leads to apathy.

3. A Solution for Scotland

The alarming rate of disrepair reported in the 2010 *Scottish Housing Condition Survey* highlighted the need to change building owner behaviours and their approach to maintenance and repair. In 2012, Stirling City Heritage Trust produced a *Scoping Study* report for Historic Scotland (now Historic Environment Scotland) which set out the compelling evidence for the need of a maintenance scheme to help support building owners in Scotland and outlined how this might be done. As a result of the report, Historic Scotland commissioned a five-year *Traditional Buildings Health Check* (TBHC) pilot in 2013. The pilot was funded by Historic Scotland and the Construction Industry Training Board (Scotland) and was designed and delivered by Stirling City Heritage Trust.

Figure 2. Serious high-level repair issues frequently go unnoticed and unchecked for years

Figure 3. The Traditional Buildings Health Check was established in 2013

The service was based on the European Monumentenwacht model. Monumentenwacht had been operating for several decades in the Netherlands and Flanders;

it had made a significant impact on the condition of the historic built environment by providing an impartial, subsidised expert building inspection service. The Scottish pilot adapted the European model to suit the physical and cultural context of Scotland's built heritage. The pilot was established in Stirling, a small city with a good representation of different traditional building types. Stirling City Heritage Trust already had an established network of local contacts and knowledge of the traditional building stock.

The *Traditional Buildings Health Check* was open to any traditional (pre-1919) building, home or business, public or community building within the Stirling city boundary. The service was available to all traditional building owners – not just those in listed buildings or within conservation areas. It was hoped that the service would reach a broad range of building owners and building types. Buildings with multiple owners only needed one owner to become a member in order to access the inspection service. For a modest annual membership fee (typically £45), building owners could access:

- Year-round support and impartial expert advice
- Affordable comprehensive external building inspection (typically £150)
- An easy-to-understand condition report with priority tasks for the next 12 months
- A free follow-up meeting with the inspector
- Educational events, newsletters and dedicated members' website with tips and advice
- From 2015, a small grant for eligible external repairs

Figure 4. Members received a free follow-up meeting with the inspector

Location including photograph or sketch of the overall area such as a roof plan or elevation

Ref	Element	Defects present & recommended repair priority	
1.1.10	The part of the building in focus	Repairs, replacement or recommended investigations should be carried out at the first available opportunity and in less than 12 months. Failure to attend to these defects may cause further deterioration or damage elsewhere or create a safety hazard.	1
		Repairs, replacement or recommended investigations are required and works can be phased to make best use of resources and any access required. If not attended to these defects may be elevated to a higher priority.	2
		The condition of the building element is consistent with age. No repair or replacement is currently needed. The element should be regularly inspected and maintained as necessary to reduce the possibility of failure.	3

5.5.4	Facings	Paint to the facings on the two dormers is failing, D6 is also obscured by ivy growth. Pics 47, 57	2
5.5.5	Windows	Most windows are replacement double glazed units. Window to the stairwell is timber sash and case, paint failure across the timber, but the timber is in fair condition. Window mastic failure and failure to the window putty. Window was not checked internally for functionality. Pics 62, 68, 72	1
5.5.6	Doors	N/A	

 34	 38	 41
 45	 47	 48

Figures 5 and 6. The inspection findings are laid out in an easy-to-understand report. The urgency of any recommended repair or maintenance work is indicated both by number and colour (eg. 1- red = urgent/ immediate action required)

4. Findings

Providing easy-to-understand, prioritised building inspection reports proved to be an effective way of improving property owner knowledge, which was supplemented by a series of informative members' seminars. Property owners felt more confident commissioning repair work once they fully understood the condition of their property. Ultimately, it helped them to spend their money wisely, on the most effective maintenance and repairs. A key success of the pilot was that members trusted the service and the advice it provided.

As well as impacting owner behaviour, the inspection reports also included physical climate change adaptation measures where appropriate. This included advice such as replacing mortar fillets with lead watergates, using lime-based mortars for repair or replacement pointing or increasing the capacity of rainwater goods where appropriate.

By the end of the pilot period, nearly 300 members had joined the service, 144 buildings had been inspected and repairs had been commissioned to an estimated 120 properties. 88% of the buildings inspected required work within the next 12 months, while 63% required urgent/immediate repair or maintenance. In many cases, the reports identified poor-quality or inappropriate repairs and long-term neglect of high-level masonry and chimneys which owners were often unaware of.

Overall feedback from members was positive and highlighted the sense of reassurance that the service provided. Members felt more empowered and motivated to act. A survey of members showed that the service:

- Encourages owners to use the right materials and techniques
- Encourages owners to do more repair work than would be the case otherwise
- Encourages owners to do the repair work quicker than would be the case otherwise

Figure 7. A key success of the pilot was that members trusted the service and the advice it provided.

The pilot proved that this type of inspection-service can help building owners to change their approach to the care of their buildings and effect cumulative change in the condition of a region's pre-1919 housing stock. The *Traditional Buildings Health Check* continues to be delivered by Stirling City Heritage Trust as a core part of their operation.

5. The Future

In 2019, the need for a more proactive approach to building maintenance in Scotland remains. The 2018 Scottish Housing Condition Survey reported that 73% of pre-1919 buildings require repairs to critical elements.

The Stirling pilot has acted as a 'proof of concept'; it demonstrates the potential of a Traditional Buildings Health Check service to affect widespread change and provides a starting model for delivery of the service. In late 2019, Historic Environment Scotland commissioned a report to explore options for delivering the service in three additional locations - Fife, Perth & Kinross and Falkirk - with identified partners. The report, which includes a series of recommendations, was presented in February 2020. Historic Environment Scotland is currently exploring funding options to support delivery of additional Traditional Buildings Health Check services based on the recommendations outlined in the options appraisal report.

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Managing the World Heritage Site Røros Mining Town and the Circumference

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Abstract

The World Heritage Site Røros Mining Town and the Circumference is located at 600-700 meters above sea level, in the middle of Norway. Most of the buildings in the area are made of wood and adopted to a typical inland climate with little perception and cold winters.

We are experiencing a gradual climate change in the area. The winters are getting shorter with several periods of temperatures above freezing point. The summers are getting warmer and we are experiencing more rainfall and wind in parts of the year. These changes are affecting buildings and other types of constructions. At the same time buildings are being used in a different way than before. To solve these problems its necessary to find technical solutions that doesn't affect the cultural heritage values in a negative way.

Keywords – Wooden buildings; temperature; roof construction; comfort; microclimate

1. Røros Mining Town and the circumference

The World Heritage Site Røros Mining Town and the Circumference is one of 8 World Heritage Sites in Norway. Røros is located just south of the middle of Norway, 600-700 meters above sea level, close to the Swedish boarder. The Town is surrounded by mountain plains, which for a long time were deforested.

The Town was established in 1644 as a result of the discovery of copper ore in the area. Norway was in this period in union with Denmark, and the Danish- Norwegian king Kristian 4 (1588-1648) encouraged to search for ores and minerals around the kingdom. The first smelter was completed by the Hitterelva river in 1646 and the town gradually grew up around it. The same year the king signed a letter of privileges for a circumference of four miles with the Storwartz mine at its centre. With the setting of the Circumference, Røros Copper Works gained considerable rights. Inside the area the company had a monopoly on exploitation of all mineral, forest and water resources, and the farmers living inside the area were required to work for the company.

Figure 1 Røros about 1870

The Town houses are, in reality, clustered farming properties, where the main building faces the street (fig. 1). From the street a gate leads into a courtyard, where you find the different outbuildings required for animal husbandry, like stables, cowsheds and storage rooms for hey. Most of the buildings are made of wood. The residential houses and the buildings for animals, that needed insulation, were mostly timbered buildings. Other kind of storage buildings were half-timbered constructions. In the 1700s only a few buildings had panelling on the outside, but during the second half of the 19th century this became more common, especially with the introduction of the Swiss style. The traditional roof construction up to the second half of the 19th century, was sod roofing with layers of birch-bark underneath. In the late 19th century slate roofing became the most usual roof construction in the town.

In the late 1970s the town centre became a conservation area with the establishment of different zoning plans. These were relieved by a new area plan in 2019. The main purpose is to preserve the town as a monument of cultural heritage. The plan has strict regulations to protect buildings and street patterns and regulate methods of repair and types of materials to be used. In addition, about 80 buildings are listed under the Cultural Heritage Act.

The Town was inscribed on the World Heritage List in 1980 based on criteria (iii), (iv) and (v). In the justification statement ICOMOS writes that: "Røros is an extensive mining settlement dating from 1644….. the numerous surviving buildings represent the Norwegian tradition of wooden construction that flourished in the eighteenth and nineteenth centuries. The buildings reflect the dual occupations of the inhabitants, mining and farming, the domestic groups being arranged as compact farmyards. ….an outstanding survivor of a traditional kind of human settlement built in traditional methods of construction" [1]. In 2010 the site was extended to include the cultural landscapes that reflect why the town was established and how it functioned, like the mines and the agricultural landscapes surrounding the town. The new name of the site became Røros Mining Town and the Circumference.

2. Climate Change Affects the Built Heritage

Røros has a typical inland climate with little precipitation and cold winters. With an altitude of 600-700 meters above sea level the summers are generally short and cold. The average annual temperature from 1961-1990 has been just above 0 degrees C. The lowest temperature registered dates from 13th January 1914, with -50 degrees C [2].

Today we are experiencing a gradual change of the climate in the area. Since 1985 the temperature in the region has gradually increased [3] The winters are getting shorter with several periods of temperatures above freezing point and rapped changes in temperature. This winter there has been hours or days with temperatures above 0 degrees C almost every week. At the same time the amount of snow this winter has been bigger than normal, but we have also had some days with rain. We are also observing changes during the summers. The last few summers have had periods of drought with high temperatures over several days.

The changes in climate and temperature are affecting buildings and other types of constructions. We are observing that buildings decay faster, and that some types of constructions/building details that isn't protected from rain are becoming especially vulnerable (fig. 2). Since most of the rain in the summer are falling straight down its especially the lower parts of buildings that are affected. The combination of high moisture and high temperature seams to cause a microclimate that is vulnerable to growth of brown-rot fungi under the surface of the materials [4]. This can over time lead to serious damage in the building construction.

Figure 2 Damage caused by brown-rot.

Today buildings are being used in a different way than before. People today have other requirements for comfort. Temperature indoors are often higher than before and in combination with rapid changes in temperatures outside, this can lead to problems with the traditional technical solutions related to roofs. The last few winters there has been an increase in technical problems related to icing on roofs. The reason is probably a combination of higher temperature on the first floors and frequent shifting in temperatures above and below 0-

degree C. The traditional roof constructions have little or no insulation and no ventilation between the insulation and the outer roofing. This makes the roofs especially vulnerable for icing. Icing doesn't have to be a big problem, but it can lead to damage on gutters and in worse case cause leaked into the construction.

Today there are still a few residential buildings that has traditional roof constructions consisting of birch-bark and sod. To avoid leakage from these roofs people traditionally had to remove the snow from the roofs. The snow insulates the roof and the hot air from inside made the lowest part of the snow to melt. When the water was freezing and melting it found its way through the birch layers and caused leaked. If the snow was removed from the roofs the chance for leaked was smaller. In addition, the temperature inside was usually not so high.

3. Solutions

The last years local authorities, craftsmen, entrepreneurs and specialists have tried to address the different technical problems we are observing on the built heritage in the World Heritage Site. Considering that there are so many different types of buildings, building materials and constructions, the problems differ and the solutions. A common approach has been to try to find technical solutions that doesn't affect the cultural heritage values in a negative way, and at the same time try to minimize the risk of damage on the objects and find solutions that has an acceptable duration.

The last years we have learned that the microclimate can be crucial for the lifetime of materials made of wood. Factors such as wood moisture and temperature play an important part in the deterioration of wood. If one can reduce the moisture and temperature in the wood the materials becomes less vulnerable to rot. When restoring wooden buildings today we are trying to find technical solutions to prevent some of the damages that has happened in the past, and at the same time is either traditional or doesn't affect the cultural heritage values in a negative way (fig. 3). In this part of Norway there hasn't been any tradition to treat timbered buildings on the outside with products like, tar to make in more resistant against decay.

Figure 3 Solution to avid rot damage.

In the winter of 2018, there was discovered a huge number of icicles hanging from the roof, windows and upper parts of the wall on a building in the town (fig 4). The reason behind the problem was probably a combination of lack of enough ventilation in the roof construction, installation of a new ventilation system on the attic of the building, and a huge amount of snow melting on the roof. The solution was to extend the vents along the raft of the building to let more of the hot air to escape before coming up through the upper layers of the roof and cause the snow to melt (fig 5). The solution entailed only a small intervention in the façade of the building.

Figure 4 Icicles hanging from the roof and walls.

Figure 5 The vents have been extended.

In 2018 there was discovered leakage from a traditional sod roof on a residential building in the town. Water was coming in through the ceiling by the walls and there were big icicles hanging from the roof (fig 6). The roof had been completely changed in 2005 and redone in the traditional way with several layers of birch-bark. The reason behind the leakage was probably hot air causing snow on the roof to melt. In 2019 the roof was repaired, and it was decided to replace the traditional roof construction with a modern form of sod roof that had been adapted to take into account the cultural heritage values of the building. The new construction has a waterproof membrane instead of birch-bark and a layer of ventilation between the insulation and the membrane to get rid of the hot air from the rooms inside. The new construction seems to be working fine and it has only slightly altered the proportions of the building (fig 7).

Figure 6 Icicles from the roof. Photo: Røros Museum

Figure 7 After restoration.

4. Summary

The last years we are beginning to experience how climate change are affecting the built heritage at the World Heritage Site at Røros. Rapid changes in temperature, more rain- and snowfall and higher temperatures both summer and winter, affects the wooden buildings in different ways. In the future these symptoms will probably become more visible. At the same time buildings are being just in a different way than when they were first constructed. People have other demands for comfort today and this affects the buildings. To cope with these changes, we need to address the problems, and find solutions that secure the cultural heritage values over a long period of time.

The examples shown in this article are some of the challenges we are facing concerning the built heritage, as a consequence of climate changes. The problems we are observing and dealing with today are probably just the beginning. Our experience so fare is that it is possible to find solutions that both deals with technical problems and doesn't affect the cultural heritage values in an unacceptable way. However, it is necessary to monitor the exposed parts of the built heritage over time and see how they are managing.

Most of the building types and constructions we find at Røros is common in the most of Norway, although the climate can vary. There is therefore likely that the experiences and knowledge gathered in Røros can have important relevance to other sites both in Norway and in other countries.

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Session 4: Building retrofit and fabric assessments

Session chair

Carsten Hermann, Historic Environment Scotland

Presentations

Climate change impact on hygrothermal performance of energy-retrofitted historic buildings: numerical simulations of internally insulated masonry walls in South Tyrol

Lingjun Hao, Eurac Research, Italy

Hygrothermal performance of an old building with log walls from the region of Vestfold in Norway

Petros Choidis, Oslo Metropolitan University, Norway

Energy Pathfinder: Approaching near zero energy in historic buildings

Kevin McCartney, University College Cork, Ireland

Climate change impact on hygrothermal performance of energy-retrofitted historic buildings: numerical simulations of internally insulated masonry walls in South Tyrol

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Abstract

Traditional architecture represents an important part of the built stock in the Alpine region of South Tyrol (Italy) and improving its energy performance is crucial for its conservation. However, forecasted climate change might impose great risks for the hygrothermal performance of historic buildings after their retrofit. This paper explores the interaction between climate and the performance of retrofitted historic buildings based on the analysis of local weather conditions and the identification of homogenous climatic zones. For each climatic zone, the traditional constructions are defined, and a tailored climate projection that considers not only temperature but also the combined effect of precipitation and wind is created. Finally, the future hygrothermal performance of traditional constructions is simulated, combining different masonry wall constructions and internal insulation systems. It is found that there will be increasing condensation risks in retrofitted granite walls in the colder areas of South Tyrol due to changes in the future climate.

Keywords – Climate change; historic buildings; energy retrofit; material degradation

1. Introduction

The relationship between culture heritage and climate change has been widely discussed as a multifaceted and multidirectional nexus. Climate change is an increasing challenge for the conservation of the built heritage. Its impacts could lead to accelerated degradation or loss of culture heritage [1]. It could cause both disaster risks and chronic degradation risks. Weather- and climate-related natural hazards, such as river/coastal floods, landslides, forest fires etc. could cause catastrophic failure of the historic buildings. Buildings exposed to natural hazards attract much attention because of the immediacy of the losses. On the other hand, cumulative degradation-risks are increasing due to climate change. For instance, the temperature increase in winters could lead to greater prevalence of insect pests and fungal attack, warping of timber elements, staining and discolouration of masonry [2]. In this regard, chronic risk assessment and adaptation are necessary to ensure buildings' resilience to new climate conditions.

Since 2009, the European Commission addressed the adaptation to climate change by setting up a framework [3]. By 2018, more than 25 member states established national adaptation strategies [4]. Comparing to climate adaptation actions, climate mitigation initiatives started much earlier, dating back to 1990 [5]. It is estimated that the retrofit of European dwelling stock built before 1945 could save up to 180 Mt of CO_2 per year afterwards [6] and improve the thermal comfort of occupants. However, the combined effect of energy retrofits and climate change could further increase the risks of degradation. Moisture related risks are likely to increase if more extreme precipitations are found in combination with inappropriate retrofit interventions that limit the drying capacity of walls [7].

2. Methodology

2.1 Present climate and Future projections

The present climate of South Tyrol has been analysed and subdivided into three climatic zones based on temperature and precipitation [8]. For the future climate, projections were taken from four regional climate models that simulate the most likely changes in future temperatures and precipitations. A high-emission greenhouse gas scenario (Representative Concentration Pathway RCP8.5) was adopted to obtain the worst climate change projection. The future climate model data has been bias-corrected and downscaled for each of the three climate zones in South Tyrol. Present and future scenarios contain multi-year climate data to reflect the long-term climate conditions in simulations.

2.2 Numerical simulations and reference constructions

To assess the impact of climate change, the hygrothermal performance of retrofitted walls is calculated using numerical simulations (Delphin 6.0 in this case). Both the wall construction and the characteristics of internal and external climates have a significant influence on the hygrothermal performance of the envelope. Table 1 presents the defined wall characteristics and boundary conditions. Further details on the characteristics of the existing materials and construction typologies can be found in [8]. Two internal insulation systems commonly used in South Tyrol are assessed concerning their hygrothermal performance: 1) vapour open system (VO), consisting of 12cm wood fibreboard, 2) vapour-tight system (VT) consisting of 12cm wood fibreboard with vapour barrier with an sd-value of 7.72m. For the masonry wall, the insulation panels are fixed to the internal side of the historic walls through adhesive or mechanical fixing. Afterwards, an internal finish is applied with or without a vapour barrier to the insulation layer (Figure 1). For the wood wall, the vapour-tight system is commonly applied. Similar to masonry walls, the wooden walls are cleaned and restored before the energy retrofit.

Then a vapour-open, waterproof and wind tight screen is placed on the inner side of the wall. The insulation layer is fixed on the screen and a wood panel is installed as a local custom (Figure 1).

Relative humidity (RH) is assessed in between the insulation and wall, as shown in Figure 1. The initial RH value in the masonry walls in future scenarios is set as the RH value resulting from the simulations in the present scenario. The wall annual index is an important parameter estimating the quantity of wind-driven rain (WDR) impacting a wall of any given orientation, and it is calculated according to EN 15927-3 [9]. The most exposed orientation is used in the simulations.

Table 1 Parameters and values used in the hygrothermal simulations

Input parameter	Value				
	Climate zone I	*Climate zone II*		*Climate zone III*	
Wall constructions	Sandstone wall	Granite wall	Wood wall	Granite wall	Wood wall
Insulation system	VO/VT	VO/VT	VT	VO/VT	VT
Wall orientation (degree from North)	180° (South)	270° (West)		90° (East)	
Wall indices	0.10	0.14		0.23	
Indoor climate	DIN EN 15026/WTA adaptive indoor climate model: temperature ranges from 20 to 25°C; relative humidity ranges from 35% to 65%				

VO=vapour open insulation system; VT=vapour tight insulation system

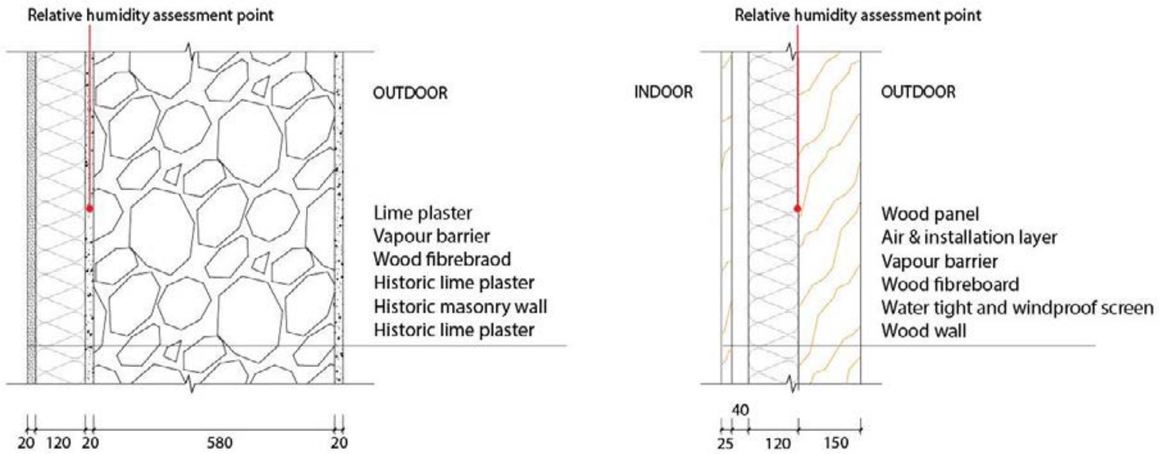

Figure 2 Reference constructions. Left: masonry wall with internal insulation; Right: wood wall with internal insulation.

2.3 Risk assessment

Condensation occurs when the water vapour pressure exceeds the corresponding saturation vapour pressure. When assessing the interstitial condensation risks in our cases, the over-hygroscopic moisture range (the moisture range above 95% relative humidity [10]) is also considered as a risk range since it is particularly relevant for the durability of any structure.

Fungal degradation and mould growth occur in this range [11], and wood fibreboard used in energy retrofit is highly vulnerable to fungal and mould as a bio-based material [12]. The number of hours within the over-hygroscopic moisture range help quantifying the risk of interstitial condensation and material degradation. However, condensation can only cause substantial damages if occurs persistently. Therefore, the risk is further divided into three levels considering the possible evaporation of the moisture content. The risk level thresholds are presented in Table 2.

Table 2 Proposed risk thresholds for the hygrothermal assessment of insulated wall

	No risk	Low risk	High risk
Risk levels	Highest RH of all the simulated period is <95%	Highest RH is >95% in less than 50% of the simulated period	Highest RH is >95% in more than 50% of the simulated period

3. Future climate change

For each climate zone in South Tyrol, four climate projections are generated (M1,2,3,4), and the temperature increase differs (Table 3). The temperature increase in M2 and M3 is higher than that in M1 and M4 in all three climate zones. The changes in precipitation vary among different climate projections and climate zones. In Climate zone II, the amount of WDR increases in near future scenario (F1: 2041-2050) and far future scenario (F2: 2091-2100), in M1 and M3; In M2, the amount of WDR increases in F1 and then decreases in F2; and in M4, the amount of WDR decreases in both F1 and F2.

Table 3 Average temperature increase compared with present scenario

	Climate zone I				Climate zone II				Climate zone II			
	M1	*M2*	*M3*	*M4*	*M1*	*M2*	*M3*	*M4*	*M1*	*M2*	*M3*	*M4*
F1	0.90	2.23	1.16	0.67	0.47	2.13	1.29	0.66	0.50	1.53	1.38	0.56
F2	3.04	6.16	5.13	3.22	2.84	6.11	5.61	3.31	3.03	5.17	5.67	3.10

4. Condensation risks in future climate scenarios

A summary of the obtained results is presented in Table 4. In Climate zone I, the RH of all the retrofitted walls is in the safe range in all studied scenarios. In Climate zone II, the granite wall retrofitted with a vapour-open system (VO) shows no condensation risks at present scenarios. However, there is condensation risk in the near future (F1) under all climate projections. In the far future (F2) scenarios, condensation risk only appears with M1 climate projection. When looking at the number of risk-hours, it decreases from F1 scenarios to F2 scenarios in all the climate projections. It could be assumed that the vapour-open system is an appropriate retrofit option for the granite wall at present, from a moisture risk point of view, but it will lead to risks within the service life of the insulation. And yet, it becomes a safe retrofit solution in the far future again. No condensation risk appears in granite walls retrofitted with vapour-tight system at present scenario while a low risk is present in most of the future climate projections. Compared with the vapour-open system, the vapour-tight system could lead to condensation risk even in F2 time scenarios.

Table 4 Risk-hours in reference constructions

Climate zone	Wall construction	Insulation systems	Average No. of hours above 95% per year								
			P	*F1M1*	*F1M2*	*F1M3*	*F1M4*	*F2M1*	*F2M2*	*F2M3*	*F2M4*
I	Sandstone wall	VO	0	0	0	0	0	0	0	0	0
		VT	0	0	0	0	0	0	0	0	0
II	Granite wall	VO	0	1181.9	133.3	348.9	741.2	44	0	0	0
		VT	0	285.9	84.3	182.4	289.2	110.4	0	53	199.5
	Wood wall	VT	0	0	0	0	0	0	0	0	0
III	Granite wall	VO	2711.1	2372.7	2065.8	1817.9	2799	915.9	65.6	62.7	2020.9
		VT	0	2558.2	3538.3	2624.7	3252	1839.5	1286.7	1418.5	2530.5
	Wood wall	VT	0	0	0	0	0	0	0	0	0

*The colours of the table correspond with the threshold defined in Table 2.

In Climate zone III, the vapour-open system could cause very high condensation risk at P and F1 scenarios. The risk-hours decrease by16.5% from P to F1 scenarios on average. At F2 scenarios, the risk-hours further decrease. M2, and M3 show low risk while M1 and M4 remain at high risk. According to the results of these simulations, the vapour-open system should not be used in the case of granite walls in climate zone III neither in present nor F1 scenarios. Simulated RH in granite walls with a vapour-tight system are in the safe range at P scenario but could have high condensation risk at F1 and F2 time scenarios. M4 presents the most risk-hours achieving 3252 h/year (37.1%) at F1 scenario. At F2, the number of risk-hours with M4 decreases the least compared to other climate projections.

5. Discussion: the impact of climate change

According to future hygrothermal performance of insulated walls (Table 4), the risks imposed by climate change will not be homogenous but very much dependent on the different climate zones. In Climate zone I, the moisture content in wall decreases in future as a result of less WDR and more evaporation due to temperature increases. In Climate zone II, the number of risk-hours in retrofitted masonry walls increases from P to F1 time scenario, and then decreases from F1 to F2 scenario. This trend is a combined result of external temperature and precipitation change. When comparing the climate data between P, F1 and F2 in Climate zone II, an increase in external temperature can be seen. This has two contrasting effects on the RH in wall. On one hand, according to the adaptive indoor climate model from WTA 6-2 [10], the outdoor temperature increase leads to the rise of indoor relative humidity, which could increase the moisture content in the wall. On the other hand, it leads to the temperature increase in the wall, which changes the saturation vapour pressure in wall, lowering the RH value in wall. Besides the temperature change, variations in the precipitation patterns may also influence the moisture content in wall. During F1, WDR increases in most climate projections (M1,2,3), implying more moisture content absorbed and stored in the wall. Looking at the retrofitted granite wall (with VO, and M1 climate projection), RH in wall at F1 scenario is the highest and it is followed by that at P scenario and F2 scenario (Figure 2). The moisture content and the temperature in the wall could well explain this phenomenon. The moisture content at F1 is higher than that at P (Figure 3), while the temperature rise in wall at F1 is very limited comparing to P (Figure 2), resulting in higher RH and more risk-hours. At F2 scenario, there is less moisture content and higher temperature in-wall; lowering the RH in the wall. The moisture content is influenced by the indoor RH, WDR and the temperature in the construction. Due to the external temperature growth, indoor RH increases the most at F1 scenario, which enhances the vapour diffusion across the wall. Moreover, the WDR witnesses a rise the most at F1 scenario, further intensifying the moisture content of the construction. On the contrary, the wall's temperature does not increase a lot, limiting the increase of the moisture evaporation from the wall. At F2 scenario, even though the indoor RH and WDR rise comparing to P, a significant temperature increase accelerates the evaporation and leads to less moisture content accumulation.

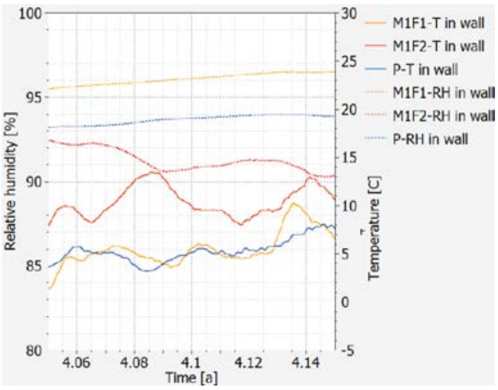

Figure 3 RH & T in retrofitted granite wall (VO) in Climate zone II during condensation period

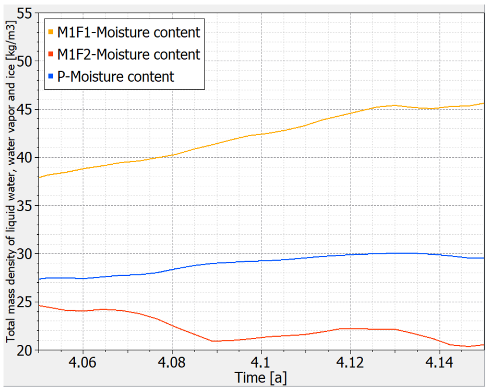

Figure 4 Moisture content in retrofitted granite wall (VO) in Climate zone II during condensation period

In Climate zone III, the RH in granite walls with a vapour-tight system remains under the critical threshold at P scenario, but it increases over time (Figure 4), and the moisture content accumulates as a consequence of the limited drying potential of the vapour-tight system (Figure 5). Although the accumulated moisture content slowly dries out in F1 and F2, the RH in wall exceeds regularly the safe threshold.

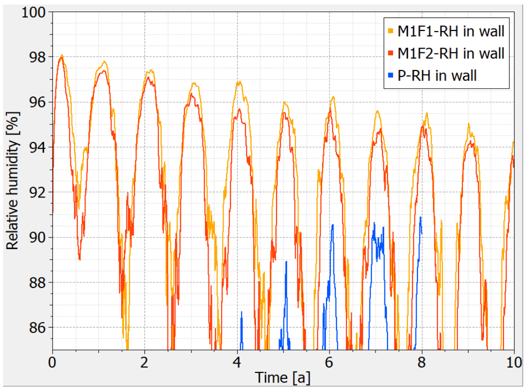

Figure 5 RH in granite wall (VT) in Climate III

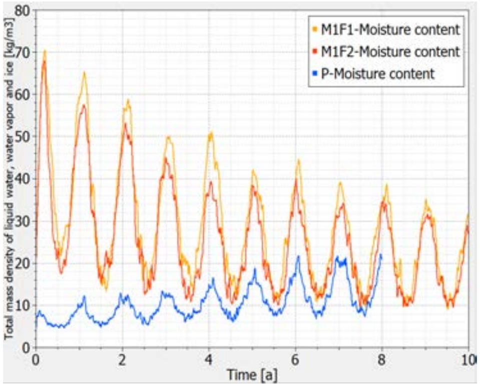

Figure 6 MC in granite wall (VT) in Climate III

6. Conclusion

The hygrothermal performance of retrofitted historic constructions in South Tyrol is assessed under present climatic conditions and four future scenarios. According to the results, several retrofit solutions that currently are commonly used could lead to condensation risk in future, especially in the colder area of South Tyrol, due to a combined result of increased external temperature and precipitation. When using the current normative design curves (DIN EN 15026/WTA 6-2), the external temperature increase leads to higher levels of internal RH. This further grows the vapour diffusion across the wall and with that the moisture content in the retrofitted wall, that in combination with increased WDR scenarios could lead to dangerous conditions for the durability of historic masonries. To ensure the conservation of historic buildings, adaptive retrofit solutions are needed, and these should be defined based on a clear awareness of the potential risks.

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Hygrothermal performance of an old building with log walls from the region of Vestfold in Norway

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Abstract

Emphasis is currently given to the impact of climate change on cultural heritage sites and buildings. In this study the climate change impact on the hygrothermal performance and the biodeterioration risk of an historic timber building is examined. The investigated construction is a two-storey building located in southern Norway and dates back to 1407. In-situ inspection revealed that the building elements are significantly damaged by fungi. Sensors have been installed inside the building in order to monitor air temperatures and relative humidity responsible for the observed damages. Moreover, climate data for the past and potential future scenarios have been acquired and used as an input in hygrothermal simulations of typical cross sections of the log walls. The calculated transient hygrothermal conditions serve as input parameters to the biohygrothermal model that is used for the assessment of the biodeterioration risk. The findings reveal insignificant mold risk. However, mold indices predicted for the future years have far higher values than the ones predicted under current conditions, which indicates the need for further and more detailed investigation.

Keywords – Historic building; biodeterioration; climate change; hygrothermal modelling

1. Introduction

Several studies underline the dramatic changes that are expected to take place in nature and environment due to the climate change [1]. In Norway, long-term climate projections up to the year 2100 have demonstrated that the country will face an increase of annual temperature up to 6.4°C and precipitation up to 18% [2]. Higher temperature and humidity levels will intensify the decay of the building materials in historic structures resulting to irreversible damages [3]. Timber historic buildings are mostly at risk because of their vulnerability to biodeterioration, such as fungi that germinate favourably under the predicted future climate conditions [3,4].

The purpose of this work is to assess the climate change impact on the biodegradation of the log walls of an historic timber construction in southern Norway. In the framework of this study both measurements and simulations are employed. The measurements concern the monitoring of the indoor environment of the building. The set of the numerical simulations is consisted of i) a hygrothermal model employed for the estimation of the temperature and moisture content in the building components and ii) a biohygrothermal model used to assess the mould risk on various cross sections of the logs on the basis of the temperature and moisture content results.

2. Methodology

2.1 Experimental site

The building under investigation is located in southern Norway, in the county of Vestfold (Fig. 1). It was built in 1407 in the region of Heierstad and thus it got the name 'Heirastad loft'. In 1957, it was moved approximately 50km south to the Slottsfjellet hill (Fig. 1), in Tønsberg, where it still stands as a property of the Slottsfjell museum. Its current location is 250m far from the coast and on 50m above the sea level.

Figure 7. On the left, a map of Norway with the county of Vestfold highlighted with red and on the right a closer view of the Slottsfjellet hill where the historic building is located

The two-storey building is founded on rocks (Fig. 2). It has a rectangular plan with its entrance in the north-west façade (Fig. 2). It is constructed of large softwood logs, most likely Scots Pine, i.e. *pinus sylvestris*, or Norway Spruce, i.e. *picea abies*, treated with tar on their outer surface. In the upper floor there are openings in the south-west, north-west and north-east facade allowing significant natural ventilation, while in the lower floor there are no wide openings. The building has a simple gable roof made of coarse wooden boards, a layer of birch bark and turf.

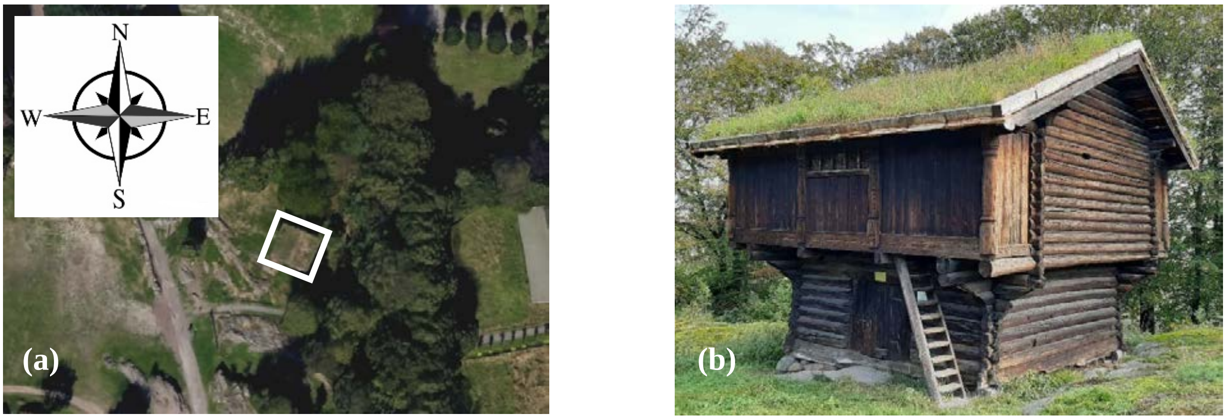


Figure 2. The Heierstad loft as observed (a) from a satellite view and (b) on site picture from south-west

The building is generally in good condition but requires continuous maintenance. The log walls of the ground floor are preserved unaltered since 1407. The upper floor was reconstructed in 1957 when the Heierstad loft was moved to the Slottsfjellet hill. Furthermore, the latest reconstruction of the roof took place in 2019. The in-situ inspection revealed that the exterior side of the log walls have cracks in several positions with the bigger examples having an average width of 0.03m and depth of 0.05m. Inside the cracks the nutritious wood that is unveiled in combination with the prevailing ambient conditions, mainly water from rising damp, condensation or rain that penetrates the cracks, form the appropriate environment for mold growth (Fig. 3(a)). Fungal growth has also been detected in the ground floor of the building in positions close to leakages (Fig. 3(b)) and joints (Fig. 3(c) and (d)). Biodeterioration damage of the log walls of the upper level is less severe.

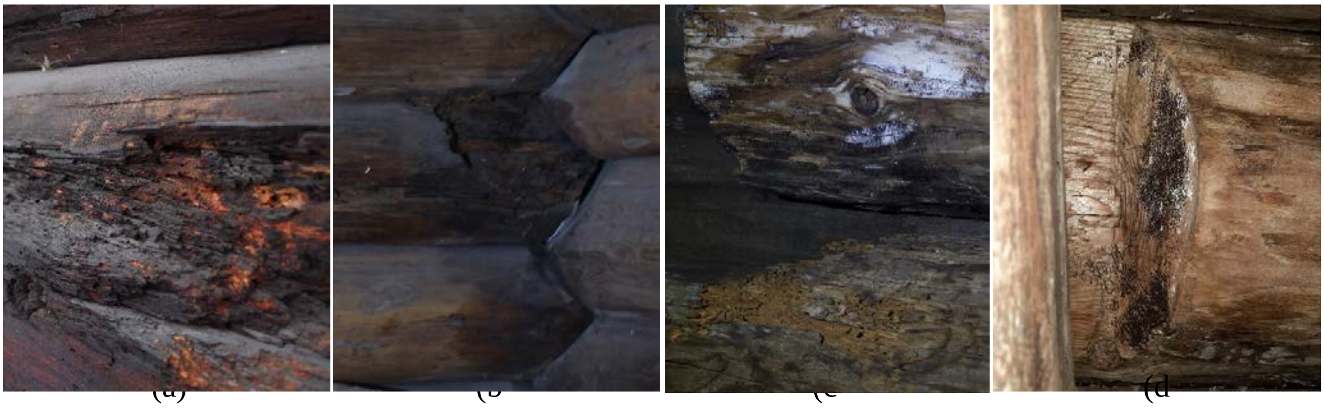


Figure 3. Fungal decay in the building's (a) exterior and (b), (c), (d) interior

2.2 Experimental set-up

Three sensors having the characteristics described in Table 1 have been installed in the building in order to monitor the climatic conditions responsible for the observed damage (Fig. 4). The first sensor is in the upper floor close to the north-west oriented opening (Fig.4(b)). The second sensor is in the middle of the largest room of the upper level of the building (Fig.4(b)) and the third sensor is in the ground floor (Fig.4(a)). For the purpose of this study a five-week period of measurements has been processed, starting from the 14th of October 2019.

Table 5. Characteristics of the sensors installed in the Heierstad loft

Parameter	Units	Range	Accuracy	Interval
Air temperature	°C	-40°C to +70°C	±1°C	30 min
Relative humidity	-	0 to 100%	±5%	30 min
Dew point	°C	-40°C to +70°C	±2°C	30 min

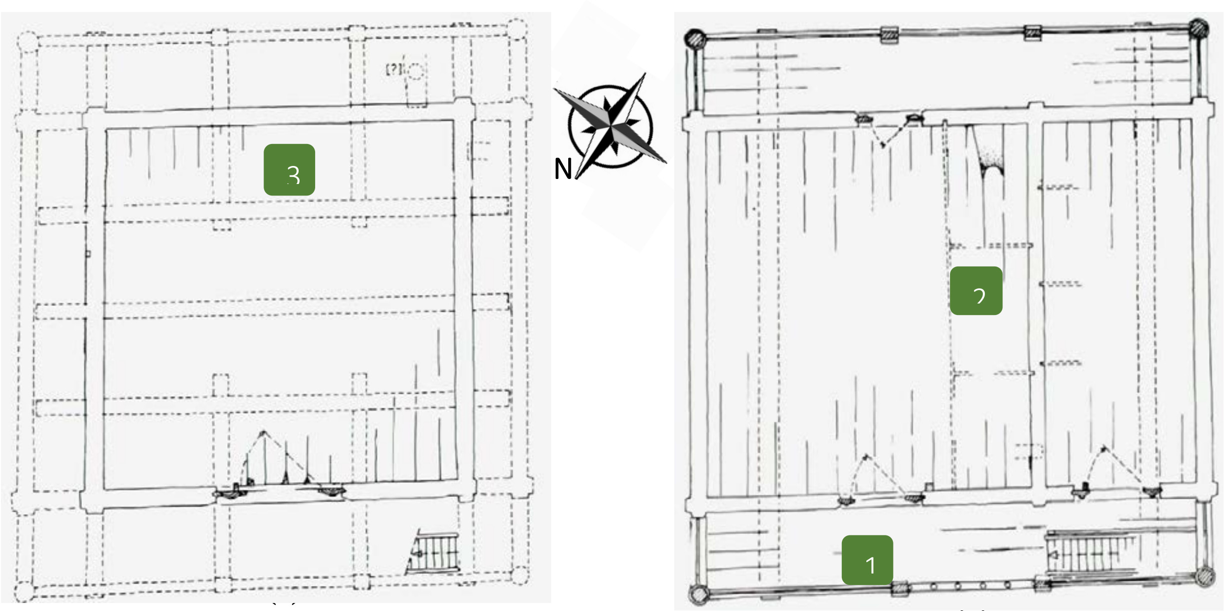


Figure 4. Sensors position in (a) the ground floor and (b) the upper floor

2.3 Assessment of the current and future climate conditions

Climate data of temperature (ϑ), precipitation (*RR*), relative humidity (φ), wind speed (*FF*) and direction (*DD*), shortwave global (H_{Gh}) and diffuse (H_{Dh}) radiation, longwave radiation (G_{Lin}) and cloud cover (*N*) were generated for the project's site (latitude: 59.2744° N, longitude: 10.4036° E, and altitude: 50m) for both past and potential future years [5]. The past climate conditions are represented by a typical year consisted of data from the period 1991-2010 for radiation and 2000-2009 for the rest of the climate parameters. The analysed future conditions correspond to the years 2050 and 2100, under the Standardized Reference Emission Scenarios (SRES) B1 and A2 of the fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) [6].

From the climate data referring to the past years [5], it is observed that the prevailing temperatures are low with an annual average of 7.8°C (Fig. 5(a)). Precipitation is moderate and well distributed throughout the year, with a mean annual value of 685mm (Fig 6). Relative humidity remains in high levels during the whole year having a mean annual value of 76%. Relative humidity fluctuates around 70% during spring and summer and around 80% during autumn and winter. In addition, the mean monthly wind speed fluctuates between 3.5m/s and 5m/s (gentle breeze, according to the Beaufort scale), while the predominant wind direction is from South. The solar radiation related parameters vary extremely over the course of the year. The energy absorbed by a horizontal surface due to short-wave radiation reaches a maximum during June with a mean monthly value of 238W/m². Almost half of this energy corresponds to the contribution of diffuse radiation. On the other hand, during December the mean monthly global radiation is only 6W/m². The cloud cover fraction fluctuates between 4 and 7 octas, with the lower values occurring during summer. Finally, the average hourly long-wave radiation from the sky fluctuates between 260W/m² and 35W/m², with the lowest values occurring during winter and the highest ones during summer.

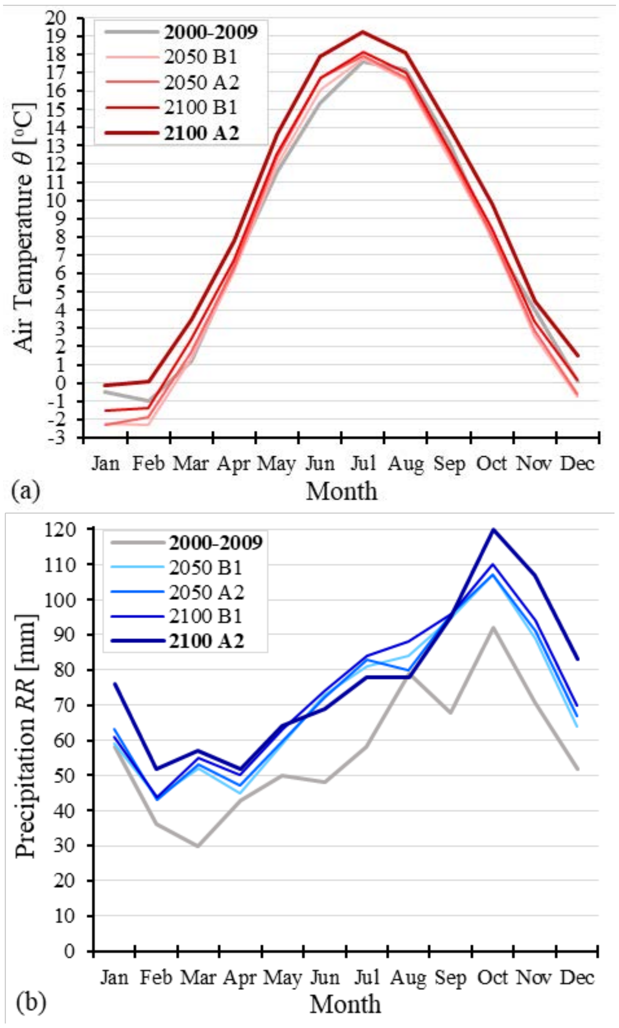


Figure 5. Mean monthly (a) air temperature and (b) precipitation for past and potential future (under SRES B1 and A2) years for the project's site

According to the data referring to the future conditions, most of the climate parameters change slightly or do not change at all. The most significant changes are predicted for temperature and precipitation (Fig. 5 (a) and (b)), the mean annual values of which are predicted to increase by 1.2°C and 36% in 2100 under the SRES A2. Temperature predictions for the other three examined scenarios (SRES B1 and A2 for 2050 and SRES B1 for 2100) indicate a decrease in air temperature during the coldest months of the year. The temperature decrease contradicts to other studies [5] and, thus, these three scenarios are not considered as potential future climate profiles.

2.4 Bio- and hygrothermal simulations

Within this study a one-dimensional hygrothermal simulation tool [7] has been used to calculate the temperature and water content of the building elements. The transient hygrothermal boundary conditions serve as the input parameters to the biohygrothermal model [8] used to predict the risk of mould growth on the building components. Within the biohygrothermal simulations a biodegradable substrate material is considered. The biohygrothermal model incorporates a transformation function allowing the expression of mould risk in terms of mould index [9].

2.4.1 Geometry, Material Properties and Boundary Conditions

Four different geometries are modelled in the one-dimensional hygrothermal simulator. The first one represents the exterior log walls that typically have a thickness of d_{log}= 0.20m and are treated with tar in their outer surface (S_d = 10m) (Fig. 7(a)). The second one corresponds to the exterior walls in positions that have cracks. In that case the thickness of the wall is $d_{log,crack}$= 0.15m and the tar treatment is considered to be removed (S_d=0) (Fig. 7(a)). The third represents the interior log walls (Fig. 7(b)) and the fourth one the timber floors (Fig. 7(c) and (d)). All analysed building components are made of softwood with the physical, thermal and hygric properties presented in Table 2 [7].

Table 2. Physical, thermal and hygric properties of softwood walls

Bulk density ρ [kg/m^3]	Porosity ε [m^3/m^3]	Specific heat capacity c_p [J/(kg K)]	Thermal conductivity λ [W/m K]	Water vapor diffusion resistance factor μ [-]
450	0.73	1500	0.09	200

In the framework of the simulations it is assumed that the exterior walls are exposed to rain, wind, short and long-wave radiation, ambient air temperature and relative humidity on their outer side, while on their inner side they are exposed to the indoor temperature and relative humidity (Fig. 6(a)). The interior walls are exposed in both their sides to the ambient temperature and relative humidity (Fig 6(b)) and the same applies to the floor configurations. It is also assumed that the indoor air temperature and relative humidity are equal to the outdoor ones. This hypothesis is reasonable, since the building has neither transparent elements nor Heating Ventilation and Air Conditioning (HVAC) system. The hygrothermal performance of the building components is assessed for the 10th year of the computational simulation, so that the results are not affected by initial conditions.

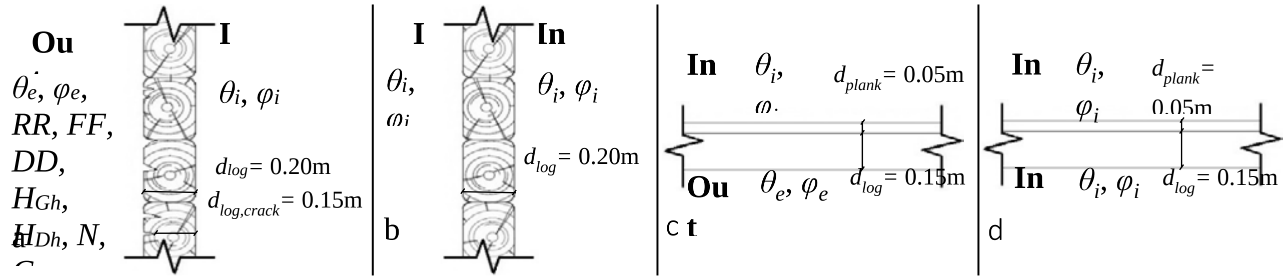
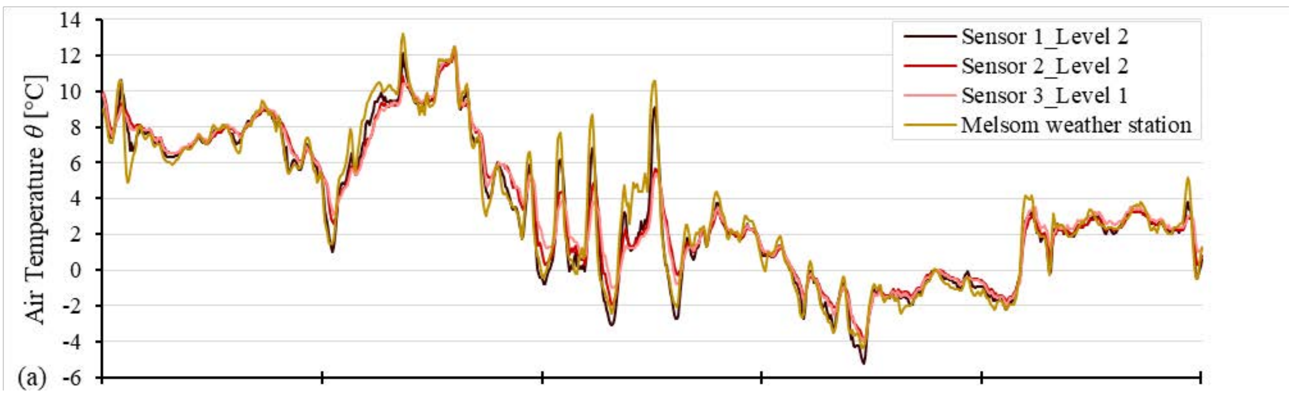


Figure 6. Boundary conditions and dimensions of the simulated assemblies

3. Results and Discussions

3.1 Measurements

In Fig. 7(a) and (b) air temperature and relative humidity measurements from the sensors and Melsom weather station (5km far from the pilot area) can be seen. Air temperature measurements (Fig. 7(a)) from the sensors are consistent with the ones from the nearby weather station, while the differences appearing in the relative humidity measurements (Fig. 7(b)) are due to the fact that the pilot area is closer to the sea compared to the weather station. Among the sensors higher range and lower mean value of air temperature is monitored first by sensor 1, then sensor 2 and last sensor 3 (Fig. 7(a)). Thus, it is revealed that the ground level is less exposed to the outdoors conditions. Furthermore, the relative humidity measurements from sensor 3 have an average value of 88% and in all cases are higher than 72%. This reveals that that the ground floor cannot be easily discharged from high moisture levels. These observations are of course linked to the poor ventilation of the ground floor and can interpret the more severe damage by fungi.



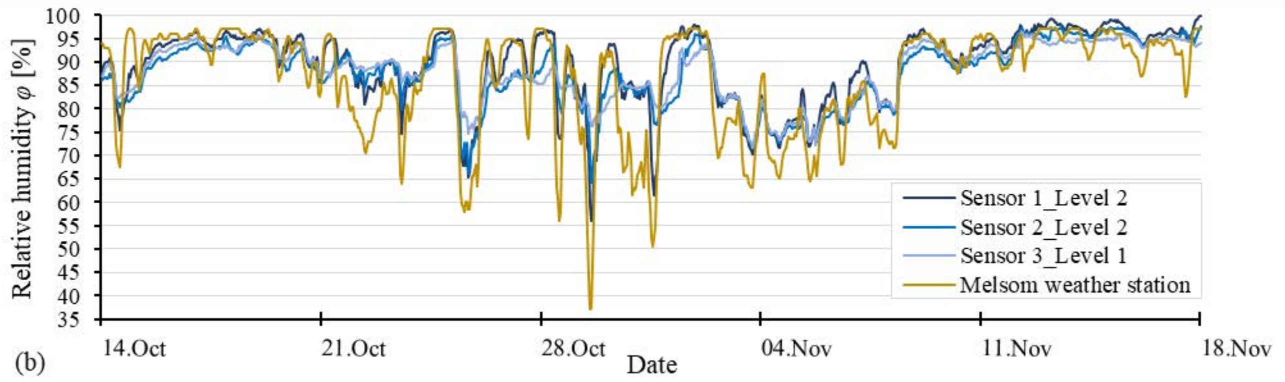


Figure 7. Measurements of (a) temperature and (b) relative humidity

3.2 Mould Risk

In Table 3 the resulted mould indices for all modelled assemblies under past and potential future conditions are presented. In all cases the mould index is calculated for a one-year period. Results reveal that there isn't significant mould risk. However, comparing the mould indices of the past years to the future ones, an increasing trend can be observed. The highest mould indices are calculated for the interior walls, while the maximum increase of the mould index is projected for the positions with cracks in the exterior walls.

It is worth mentioning that the values of the mould index are highly dependent on the climate conditions and the material properties that are considered within the hygrothermal simulations. In order to simulate more accurately the physical problem, it is important to use non-destructive methods in order to define the exact material properties. It is, also, important to take into account more scenarios about the future climate.

Table 3. Mould indices for the log walls estimated for a one-year period under past and potential future climate

Assembly	Orientation	Mould index			
		Past	*Future*	*Past*	*Future*
		Outer surface	*Inner surface*	*Outer surface*	*Inner surface*
Exterior wall treated with tar	*North-West*	0.000	0.086	0.000	0.118
	North-East	0.000	0.092	0.000	0.120
	South-East	0.000	0.072	0.000	0.097
	South-West	0.000	0.066	0.000	0.092
Exterior wall in position with crack	*North-West*	0.067	0.082	0.112	0.115
	North-East	0.063	0.089	0.117	0.118
	South-East	0.049	0.073	0.074	0.097
	South-West	0.048	0.065	0.071	0.090
Interior wall	*All*	0.188		0.205	
Floor	*All*	0.179	0.187	0.194	0.203

4. Conclusions

In this study the degradation of a timber historic building in southern Norway is examined. In-situ inspection revealed that the most critical damage on the building elements is fungal attack. More severe damage has been observed in the ground level which is poorly ventilated. Moreover, measurements from sensors confirmed that higher mean air temperature occurs in the ground level. It was also observed that the ground level cannot be easily discharged from high moisture levels. One-dimensional models of the building elements were investigated for their hygrothermal performance under past and potential future climate conditions. The calculated hygrothermal conditions were then used as an input in biohygrothermal simulations to assess the risk of mould growth on the building material surfaces. Results have shown insignificant mould risk. However, higher mould indices have been projected for the future years, with the maximum increase projected for the exterior surfaces in positions with cracks. It is worth mentioning that in a future study more climate change scenarios should be taken into account and also the actual material properties of the analysed building elements should be defined by non-destructive methods.

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Energy Pathfinder: approaching zero energy in historic buildings

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Abstract

'Energy Pathfinder' will provide support to owners of historic buildings in northern regions of Europe, who aspire to achieve the reductions in building energy use and carbon emissions, achieved by contemporary properties constructed under the stipulations of the European Directive on near Zero Energy Building (nZEB). The EU's Northern Periphery and Arctic Regional Fund supports he project, which commenced in May 2019. There are considerable barriers to energy upgrading of historical buildings. Not the least of these is concern that the upgrade work might damage the characteristics that contribute to the historical value. 'Historic' designation and value can arise from many sources, such as function, age, rarity, association with significant events and individuals, and not just the building's significance in the history of architecture. Therefore, a co-design process will be adopted, to involve multiple stakeholders in devising retrofit solutions to energy upgrading of historic buildings whilst safeguarding their cultural value.

Keywords – Historic building; Zero Energy Building (ZEB); Energy retrofit; Co-design; Stakeholder participation

1. Context

The work described in this paper started in 2019 and is being carried out as part of the 'Energy Pathfinder' programme funded by the EU's Northern Periphery and Arctic Programme. The partners coordinate activity in five countries and provide expertise in architectural design, building renovation, energy efficiency, education and training, and digital application development. The partnership will also present contrasting case studies from upgrading projects on buildings in the Faroe Islands, Finland, Ireland, Scotland and Sweden.

The partners are: Historic Environments Scotland, Landsverk in the Faroe Islands, NCE Insulation in Cork, Oulu University of Applied Sciences in Finland, Umea University in Sweden and University College Cork, in Ireland. The partners, and their consultants, will provide expertise in building conservation, the architectural design process, construction, energy efficiency, and renewable energy. This will inform the design, implementation and review of case studies, which will then inform the development of a digital tool intended to guide the owners and curators of historical buildings, through the confusing maze of techniques, technologies, principles, regulations and guidelines that must be considered when planning alterations to an historical building. The major components of the Energy Pathfinder project are illustrated in Fig. 1.

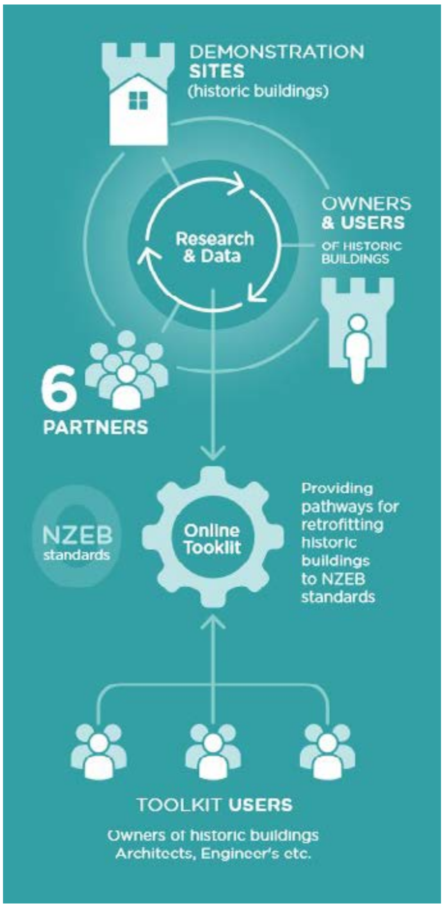

Figure 1. Diagram illustrating the components of the Energy Pathfinder Project.

2. Energy Retrofit Design Process

The case study for Cork in Ireland, began with a literature review of the extensive literature providing guidance for modifying and improving historic buildings in Ireland and the UK. The process of developing an improvement plan was represented as consisting of three linked stages: user definition, building type definition, and energy source. These stages are elaborated in Fig. 2.

Energy demands are shaped by three elements: the user, the fabric of the building, and the energy supply/conversion and control systems. Fig. 2 indicates a process that begins with a definition of the user. Different users have different occupancy patterns, different preferences for internal temperatures, and different demands for the degree of control and the complexity of the interface of control devices. The building fabric and form determines the solar gains and heat losses, and therefore the heating demands. The energy source determines running costs, security of supply, carbon emissions and other environmental impacts.

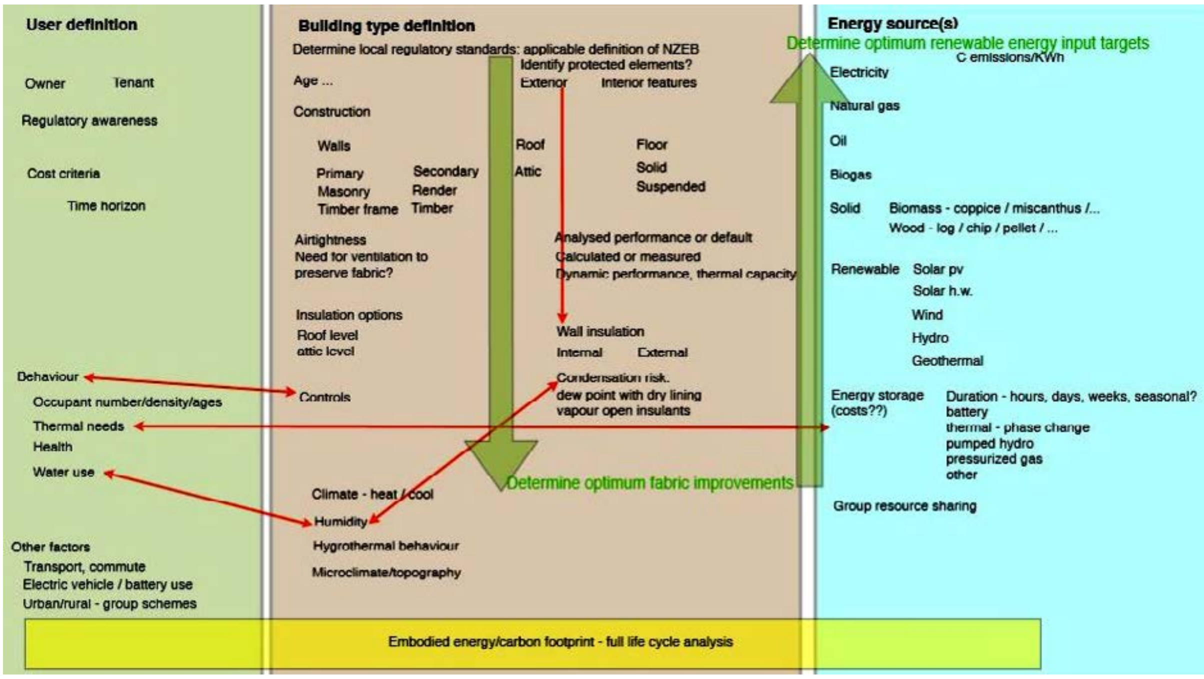

Figure 2. Energy retrofit design process:
Three areas of investigation required to prepare an energy upgrade
(Akiboye Conolly Architects, Energy retrofit design approach.)

3. Co-design Methodology

The participation of many stakeholders is an important aim underlying the development of a methodology for energy retrofitting being developed in 'Energy Pathfinder'. It is hoped that the digital tool will also play a role in supporting this aspect of the retrofitting design process, in order to involve a wide range of stakeholders and to harvest the information needed to recognise the cultural characteristics of the buildings that must be protected during the energy upgrade.

In the co-design process, a sensible first step is to identify the stakeholders who to be invited to contribute to the design, and the decision-makers for each part of the process. In the Myross House case study, potential stakeholders can be categorised as:

- consultants
- owners
- occupants
- secondary occupants (those who work in the building)
- neighbours

- authorities

Table 1. Energy retrofit design decisions mapped against stakeholders in Myross House case study

#	Energy Retrofit Decisions	Consultants	Owners/ Client Reps.	Occupants	Secondary Occupants	Neighbour	Regulatory & Guidance Authorities
A	Insulation						
1.1	Wall Internal	●	●	●		●	
1.2	Wall External	●	●	●		●	●
1.3	Wall Cavity	●	●				
2.1	Floor Above	●	●	●			
2.2	Floor Below/Internal	●	●				
3.1	Roof External	●	●	●		●	●
3.2	Roof Cavity	●	●				
3.3	Roof Internal	●	●	●			
B	Heating Controls						
1.1	Heating Central	●	●				
1.2	Hot Water Central	●	●				
1.3	Heating Local	●	●	●	●		
1.4	Hot Water Local	●	●	●	●		
1.5	Ventilation Electric	●	●	●	●		
1.6	Ventilation Manual	●	●	●	●		
C	Renewable Systems						
1.1	Visible Mounting	●	●	●		●	●
1.2	Noise Potential	●	●	●		●	●
1.3	Running Cost	●	●	●			
1.4	Maintenance Reqs.	●	●	●			

The strategy for involving each of the stakeholder groups may have to be different. Not all the stakeholders have the same financial and legal responsibilities faced by the owners. Not all groups of stakeholders have the same abilities and experience required to deal with all the decisions that must be made. There is a need therefore to distinguish between the issues that will be presented to the different groups of stakeholders, and to devise appropriate mode of communication for each group and-information type. Table 1 maps stakeholder groups to the appropriate decision-making areas in energy retrofit design. In some cases, it will be necessary to motivate participants, in other cases it will be necessary to inform and facilitate them, to enable designers to harvest the information required to safeguard the cultural and historical values of the buildings.

Figure 3. Myross House, Leap, County Cork, Ireland
(Downloaded 18 February 2020 from http://ep.interreg-npa.eu/demonstrator-sites/)

There are examples of co-design practices that might be adapted from other application fields. For example, Kankainen et al (2011) have used a 'story telling' method to encourage participation in a co-design process for service design. And Munthe-Kaas (2015) has described design interventions in which temporary construction was undertaken to provoke public controversy and participation in the design of urban public spaces.

4. Case studies

The case studies encompass different building types, from house to cathedral, and they are at different stages of development. They will therefore provide a variety of different types of guidance to the owners of historic buildings. Myross House, which has accommodation for more than 50 visitors (Fig. 3) will provide information on the co-design process and the retrofit alternatives evaluated. Construction work to upgrade the Vicars House in the Faroe Islands (Fig. 4) has in contrast, already been completed. It can be expected to provide information about the visual impact of specific techniques and the occupant and neighbour reactions to the improvement works.

Figure 4. Wooden vicarage on Faroe Islands
(Downloaded 18 February 2020 from http://ep.interreg-npa.eu/demonstrator-sites/)

There are two case studies in Finland – a Rectors House and the Town Hall in Raahe. The Tegs Kyrkan church in Umea, Sweden, is expected to provide environmental information from modelled and measured internal air movements. In Scotland, the case studies are both domestic, one of which will address the upgrading of a Harbour Master's cottage in the Orkney Islands. This is likely to provide information about the installation processes and measured performance data. In Ireland, in addition to the Myross House rural example, there is also potential to include the design of upgrading for the Cork City Cathedral of Saint Mary and Saint Anne, which is used not only for worship, but also accommodates a variety of community groups in its lower ground level. This presents interesting challenges concerning visual impacts associated with retrofitting renewable energy systems.

5. Conclusion

An international partnership will contribute to devising a methodology for the design and monitoring of environmental upgrading projects to historical buildings in the Faroe Islands, Finland, Ireland, Scotland and Sweden. The methodology will encompass technical and legislative aspects, and co-design approaches to including a variety of stakeholder in the process. Lessons from these case studies will inform the development of guidance for owners and curators of other historic buildings, and a digital toolkit will also be developed to improve the accessibility and usability of the guidance created.

Table 2. References

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Session 5: Developing guidance for conservation practice

Session chair

Kirstine Møller, Memorial University of Newfoundland, Canada, & Ilisimatusarfik - University of Greenland, Greenland

Presentations

Conservation strategies for archaeological excavated structures in an environment change future

Gavin Douglas, Historic Environment Scotland, Scotland

Think globally, act locally. Checklist for safeguarding cultural heritage interior from climate hazards

Nina Kjølsen Jernæs, Norsk institutt for kulturminneforskning, Norway

How can conservation management plans for cultural heritage be used as a tool for climate adaption?

Camilla Altahr-Cederberg & Helen Simonsson, Riksantikvarieämbetet, Sweden

Two nations, one approach: Establishing joint-nation coastal and maritime baseline data for future resilience planning; the CHERISH Project

Toby Driver, Royal Commission on the Ancient and Historical Monuments of Wales, Wales

Conservation strategies for archaeologically excavated structures in an environment change future

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Abstract

This paper considers that although archaeology and specifically archaeological structures are generally accepted to be non-renewable resources, conservation during excavation has not always been of immediate importance. The ability to conserve and manage these national assets with consideration of the predicted weather events of the 21st century is being brought further into focus. There are numerous conservation charters and guidance both nationally and internationally that have been adopted in the conservation of built structures, the conservation of archaeological finds and the process of archaeology itself. There is however a gap in guidance on the conservation of excavated structures; these shortcomings are to be identified and guidance created. This research aims to create a strategy on how to approach projects and guidance as to how this can be applied, recognizing that how a site is conserved shapes ins vulnerability to the environmental changes of climate and visitor impact now and in the future.

Keywords – Conservation; archaeology; guidance; environmental change; climate change; visitor pressure

1. Introduction and Rationale

Archaeological research provides valuable information about how people lived in the past, their everyday industries and activities and makes major contributions to the heritage and tourism industries. It is also a peculiar record consisting of items as varied as the foundations of buildings, broken pottery, monuments, animal bones or tombs, the list is almost endless (Historic Environment Scotland, 2016), (Lipe, 2000).

Archaeology is a finite, valuable non-renewable resources for research into the history of human habitation. Each archaeological excavation is a non-repeatable experiment involving the partial destruction of the resource for the benefit of advancing knowledge and understanding. This resource is constantly being depleted on a global basis with announcements of new archaeological finds recovered through archaeological excavation perhaps more frequently than ever before (Barker, 1993), (Cline, 2017), (Lipe, 1974). Excavation although destructive can be equally informative and archaeologists use their knowledge and skill to communicate their passion in a number of widely different fields. As a field of expertise, archaeology can help everyone celebrate their ancestry and diversity (Historic Environment Scotland, 2016), (Renfrew and Bahn, 2008).

In the 20th Century archaeologists made great strides in understanding the material record of past human life. Concurrently, destruction of the archaeological record increased as population growth, economic development and looting took a rising toll (Lipe, 2000). This deterioration is also attributable to a wide array of other causes ranging from neglect and poor management to increased visitor numbers and climate change (Matero, 2008). By themselves archaeological sites have no practical purpose or commercial value, this makes them uniquely vulnerable as the inability to develop ruinous structures and sites into something of value can oftentimes lead to them being preserved by record then destroyed. Modern interest should be beyond the historical and artistic importance that the remains of a given building may have; as the ephemeral traces of the human activity on earth, ruins are actually among the most evocative icons of times past (Rizzi, Preface in (Ashhurst, 2006).

Contemporary conservation and heritage theories recognise that cultural heritage is a social construction: it is the result of differing social processes that vary by time and place. As the principle investigators and caretakers of archaeological heritage, heritage professionals such as archaeologists, conservators and managers play a major role in deciding what is valued (Avrami, Mason and de la Torre, 2000), (Matsuda and Okamura, 2011). There is no doubt that archaeology and heritage are valued but what does seem to be missing is any published guidance on conservation of structures in an archaeological setting, either nationally or internationally.

The fundamental premise of this research is that the way in which a site is left after excavation influences its vulnerability to decay and degradation, limiting its availability for future generations, together with increasing realisation that the impact of future climate change and increased visitor pressure means site degradation will only accelerate. Limitations in excavation practice are therefore taking on a new significance and so this paper sets out an emerging strategy on how best to assess site vulnerability in the face of environmental change through site record review, site structure review and experimental analyses. These analyses form the foundations for new approaches and guidance for excavation practice that recognises the new significance of site conservation. The Northern Isles of Scotland together with Caithness have been selected to initiate the development of this strategy because of their diverse, well preserved and numerous arrays of archaeological sites and because the Old Red Sandstone geology from which many of the monuments are constructed, is particularly susceptible to degradation.

2. Environmental Change Drivers

2.1 Climate Influences on Archaeology

There is little doubt that the climate in Scotland including the Northern Isles of Scotland and Caithness is changing as it is on a global level. The last century has been characterised by a continuous increase in temperatures, altering patterns of precipitation and increased frequency of unpredictable and extreme weather events. Sites that may have survived well since being excavated up to the present day including the current climatic conditions, may become less able to cope with changing weather patterns caused by future predicted climate change (Historic Environment Scotland, 2016) (Historic Environment Scotland 2018). Scotland is expected to see continually wetter winters and drier summers, with more frequent intense spells of rain. This changing frequency, and intensity, of rainfall will have direct impacts on all aspects of the historic environment. On a local scale, but over a longer period of time, water is a major controlling factor in chemical, biological and physical decay processes that are particularly prolific in the deterioration of stonework. In short, if stone is exposed to increased amounts of moisture, then the speed at which it naturally deteriorates will accelerate (Historic Environment Scotland 2016).

The increase of temperatures, sea levels and rainfall patterns will increase the risks to people and built environment including historic sites and archaeology. (Kovats, Osborn and Whitman, 2016), (Harkin *et al.*, 2019). Because of the differing geography between the sites within the study, no one environmental condition will have the same impact on each specific site or region. However accumulatively throughout the study area there is a continual and increasing risk from numerous threats which if left unchecked will undoubtedly accelerate the rate of loss from sites.

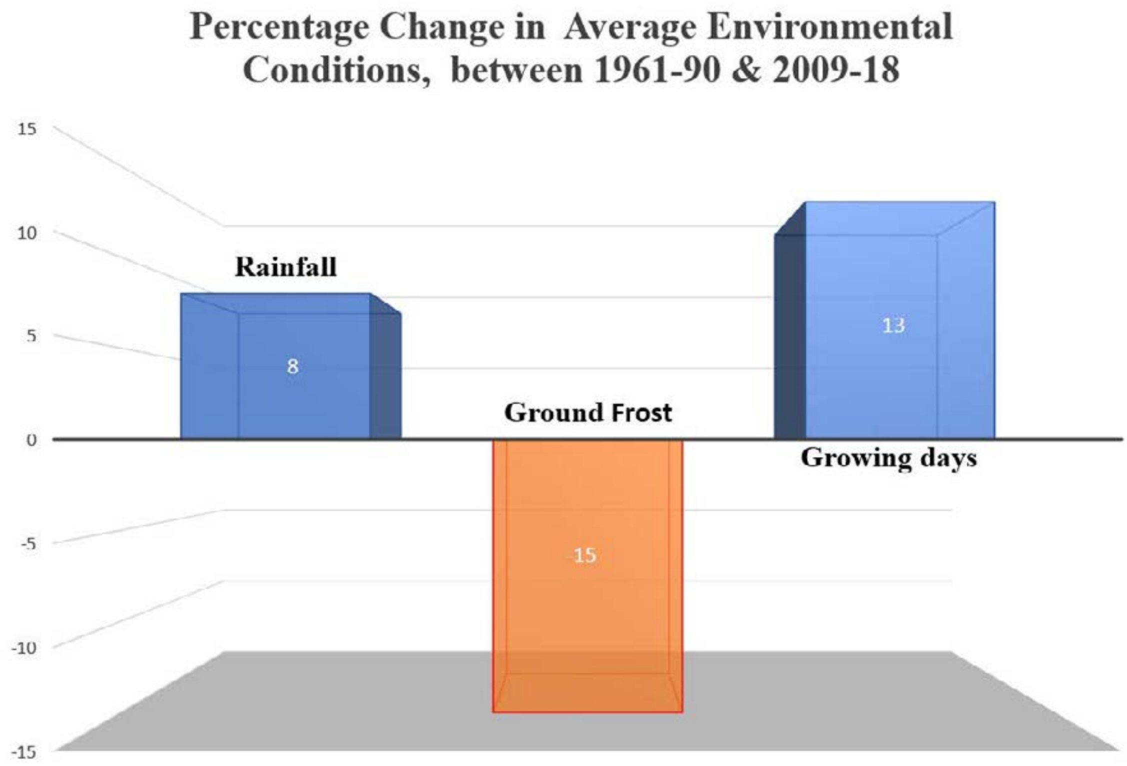

Fig1 https://www.metoffice.gov.uk/research/climate/maps-and-data/about/state-of-climate

Changes in climate as well as affecting coastal sites has the ability to impact on all archaeologically excavated sites in numerous ways, with increased rainfall heightening the risk of waterlogging the sites as well as washing out cores of some structures. A large amount of archaeological sites which remain standing dry stone walls are soft capped which as well as being there for aesthetics also protects the core of the wall from water penetration. At sites such as Skara Brae in Orkney and Clickimin Broch it has already been shown that with increased visitor numbers and wetter summers these are not withstanding the pressures they have previously, increased water ingress may also impact the manner in which the stone deteriorates. The methods with which they have been historically consolidated will also determine how and if they withstand these changes and in turn how they will retain their structural integrity.

Where excavated sites are left exposed or poorly consolidated this can lead to an increase in the rate of erosion of the stone, sandstone is particularly vulnerable to this. Stone and soil erosion can create instability, leading to collapse and loss of in-situ archaeological deposits. Additionally, and in tandem increased visitors to a site along with higher levels of rainfall can cause accelerated erosion of ground surface finishes. At some sites, this can lead ground conditions becoming impassable, with less chance of recovering due to the longer visitor season.

2.2 Visitor Impact

The ways in which historic sites are visited is also changing; Within the study area, until relatively recently the standard visitor was a family group arriving in one vehicle. In the past two decades there has been globalization, rapid societal change, significant global economic fluctuations, huge increases in tourism, and massive technological innovations (Williams, 2018). The relationship between conservation and tourism is often seen as antagonistic, and while site management planning incorporates presentation and interpretation at varying levels, they are predominantly associated with economic benefits or visitor numbers (Silberman and Callebaut 2006). The Burra Charter states Conservation requires the retention of an appropriate visual setting and other relationships that contribute to the cultural significance of the place. (ICOMOS, 2013)

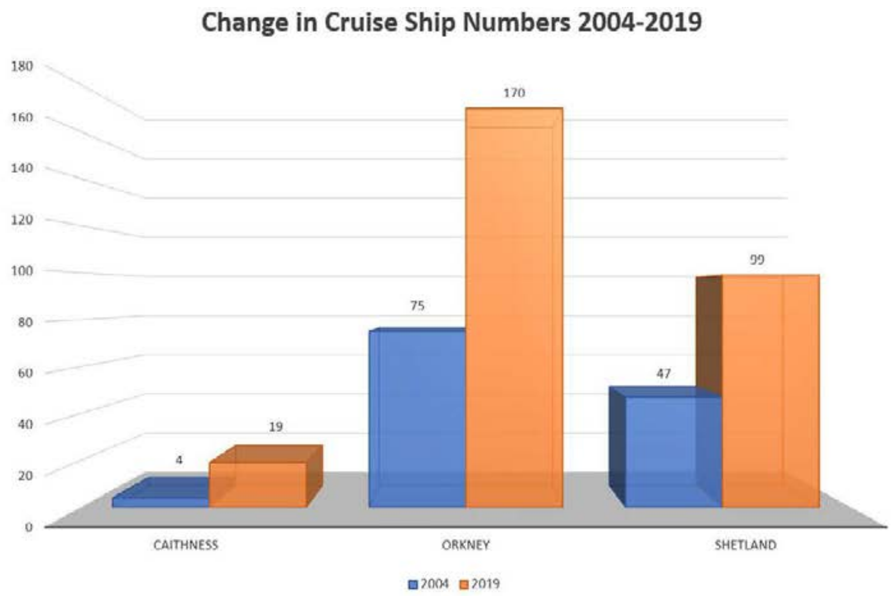

Fig2. Rise in numbers of Cruise ships. Sources Scrabster.co.uk, Orkneyharbours.com, Lerwick-harbour.co.uk

One influence has been the explosion in numbers of cruise ships stopping at Scottish ports leading to mass tourism where visitors arrive in intense bursts of numerous bus filled size groups over the course of a day; this has been a particular issue for management of Northern Isles sites (Figure 2). Additional factors which have affected the pattern and number of visitors within the study areas include a rise in popularity attributed to the appearance of sites in recent TV shows and films, and the establishment of the North Coast 500 – a formalised route to drive around 500 miles of the coast of the highlands. Both have led to large increases in visitor numbers, often to sites which had previously had minimal visits. These increases at sites, influence the levels of conservation required particularly where there is impact on the stability, form and setting of individual sites.

In addition to erosion caused by footfall on formalised pathways and interpreted routes, the dry stone structures prevelent within the study area are hugely susceptible to small scale damage caused by inappropriate access. Visitors deviating from the formal routes and pathways, often to gain a view from the highest point in the site, risk dislodging stones and deposits. Over time this can have a critical effect on the maintenance of site historical integrity.

3. Site Vulnerability Assessment

3.1 Geological setting

On a global scale Scotland is a relatively small country, it does however possess an unrivalled diversity of rocks and landscapes that tell an incredible history, of a piece of continent that has travelled the globe, been pummelled into mountains, rocked by volcanic eruptions and pulled apart along rifts and, specifically with Old Red Sandstone, along the way the climate has changed from tropical to glacial and almost everything in between. (*Scotland's Geology* -

Edinburgh Geological Society, 2018). The bedrock geology of where humans settle, especially prehistoric people, shapes how they live and crucially what structures they can build. Since the first prehistoric people started to dig for stone to make implements, rather than pick up loose material, humans have modified the landscape through excavation of rock and soil. As such, humans are geological and geomorphological agents and the dominant factor in landscape evolution, the exploitation of the landscape and its subsurface is progressed meet the needs of society is driven by changes in socioeconomic, technological, political and cultural parameters. (Price *et al.*, 2011).

Because of the sedimentary manner in which Old Red Sandstone was formed and the layers created, quarrying and collection of stone from the bedrock is relatively simple as the bedrock can cleave off in sheets. The breaking up of the geological surface can also occur naturally, giving a ready source of construction materials by natural forces and this is especially the case on the shoreline where large areas can be broken up to form manageable sections of ready-made building material. There are however some negative properties in its composition. If the stone has a large percentage of soft layers or beds within it, this can be more prone to delamination which can become progressively more extensive and damaging to the initial stone and eventually the stone around it.

3.2. Site Vulnerabilities - *Site record review.*

Scheduled sites within the study area that have a record of excavations are being researched by systematic review of the archives held by HES as well as more locally held repositories. Records go back to the 1820's and include text, plan and section drawing evidence. While sometimes difficult to source and with varying quality they nevertheless allow identification of site conservation strategies together with assessment of site condition at the end of excavation. In general, the older the site the less information is available with more recent projects having much more complete and accessible records. The emerging analyses is showing how over two centuries the extent of strategic thought and action given to the long-term preservation of the site has varied with excavation purpose, training, who was funding the excavation and the specialist academic discipline of the excavator. The analyses also indicate how conservation of sites has been augmented by later phases of conservation endeavour but ultimately how sites have been left vulnerable to the emerging environmental changes of the 21st century.

Site structure review. Drawing from the site record review a set of 8 contrasting sites with good quality drawing or photographic records of excavations are being assessed for structural changes between the completion of excavation and the present day. Detailed comparative photogrammetry is enabling this analysis and allows consideration of whether this has impacted structure vulnerability positively or negatively. These analyses are further supported by interview-gathered information with the archaeologists leading these projects and is aiding with the understanding of the scale and extent of conservation and presentation planning together with how evidence of a changing environment influenced thinking on site conservation. Together, these analyses give evidence of changing conservation strategies and their influence on site vulnerabilities over the last 200 years, how the post excavation site has withstood the intervening years and what conservation issues may be ahead given emerging environmental challenges.

Experimental works. To replicate deterioration of excavated drystone walls experimental structures incorporating standard details found on post excavation sites in the area such as soft capping, hard capping, enclosed in a building or left with a timber propped void in the wall. Using sandstone from the nearby archaeological (excavation spoil) stone they have been built at Old Scatness, Shetland. These have been measured by laser-scanning to an accuracy of xx mm and are being monitored every three months for a period of 6 years to assess change and movement. These photogrammetry-based experimental observations will give accurate and detailed findings that can be compared with archaeological sites structures to identify structural vulnerabilities associated with missing stonework, rebuilding or where there may have been archaeological misinterpretation as a result of structural change.

4. Emerging Guidance for Archaeological Practice.

The analyses of site structure review, site record review and experimental works will be integrated with the environmental drivers of climate change and visitor pressure to give robust assessments of site vulnerabilities from which good practice guides for conservation and presentation of archaeological monuments can be developed. The research will include sites at varying stages of conservation management and embed the views and positions of interest groups that include local history groups, universities and conservation trusts. Key sites to test emerging ideas include Ness of Brodgar, Links of Notland and Old Scatness together with smaller more local excavations. The project will actively co-produce conservation strategies with interviews of local communities, site directors, archaeologists, engineers and architects to give collation of best knowledge and experience of conservation works on site and the perceived challenges changing environments. It is anticipated the research will take 4 years to complete but that an initial guidance note will be circulated to interested parties for comment, edition and addition. Once completed it will be published as a *Technical Advice Note* by Historic Environment Scotland as a way of contributing to the national and international challenge on how best to shape excavation practice for site conservation in rapidly changing environments.

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Think globally, act locally. Checklist for safeguarding cultural heritage interior from climate hazards

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Abstract

Throughout the last years, there has been an increased focus on preventive work and safeguarding objects and inventory of a cultural historical importance from sudden climate hazards like fire and water. Manuals and guides have been developed in order to raise awareness on how to react when the crisis is a fact. However, there seems to be a gap between the tools developed and the practices at local levels. The aim of this paper is to give a systematic overview of good routines for safeguarding cultural heritage interiors that normally fall outside the scope of a regular risk management plan for historic buildings. The paper gives an overview of relevant guides for cultural historic interiors. Through experience from a collaborative preventive emergency project and the relevant literature, the paper presents a checklist of routines for safeguarding heritage interiors. It also reveals the need for further studies related to this topic.

Keywords – Emergency response plan; sudden climate hazards; cultural heritage interior; low-threshold solutions; mitigation measures

1. Introduction

NIKU and Norwegian Association for Church Employers (KA) started a project dealing with emergency response in three churches in Agder County in March 2019, - The Agder project. One of the aims was to find low-threshold practical solutions for mitigation measures of the church interior and inventory. We looked at how interaction between regional and national expertise can take advantage of each other and develop a better management of the churches regarding salvage rescue plans. An interdisciplinary working group consisting of owners, managers, fire fighters, salvage rescue teams, conservators and ambassadors for the municipality visited three churches looking at status quo, discussing scenarios, ascribing inventory's values, and other issues concerning both mitigation measures and salvage rescue work. A full-scale drill was undertaken in a medieval church, testing the salvage rescue plan using props for selected objects in the church. Several meetings afterwards evaluated the drill, and at a seminar the results and the evaluation were presented, and the needed strategy for improvement of emergency planning was discussed. Through this collaborative project it became apparent that a lot of international manuals and guides for preventive work regarding climate hazards and cultural heritage, are not tailored for smaller cultural heritage buildings and institutions managed by non-heritage experts.[1]

Surface treatments, decorative paint and interior details in traditional buildings require careful consideration. In addition to acting as a fuel source, they are extremely vulnerable to damage from fire and smoke as well as from fire suppression media, such as water or foam [1 (p.29)]. This invites an increased focus on interiors when working on preventive measures for fire and water damages. A literature review on the topic reveals a lack of attention to interior and inventory specifically.

When looking at disasters affecting cultural institutions worldwide, fire and flood tops the list from the period 1981-1999, followed by earthquake and war occurrences [2 (p.2)]. The National Trust also identify agents that cause damage to collections, which is topped by fire, loss and water [3]. There's no reason to believe that this has changed in the last 20 years. In the concurrent period, there has been a preventive focus through the work of ICOM, ICOM-CC, ICCROM[2], Blue Shield, Council of Europe, Historic Environment Scotland, Historic England and other large organisations regarding climate hazards for built cultural heritage and museum collections. In addition, solid work is undertaken for raising awareness on emergency response work after sudden hazards. In fact, one can state a certain overload of guides and manuals on risk hazard analysis and emergency response [4 (p.5)]. However, there seems to be a gap between the developed tools and the practices at local levels regarding emergency preparedness. Gaillard and Mercer have pointed out this problem regarding disaster risk reduction [5]. The increased importance of international treaties and manuals and the parallel growing of emphasis given to community-based and local actions, named 'glocalization', front the needs of bridging the gaps between the international and the local management [5 (p.94)]. The management of historic houses and churches might lack staff focus on fire prevention and preventive conservation, in addition to the needed focus on climatic changes and surrounding geohazards. As a result, it becomes challenging to use international manuals and guides in their preparedness tasks.

The article gives an overview of relevant international guides and papers on safeguarding historic interiors and associated emergency preparedness plans. By using the results from the Agder project, the paper presents a low-threshold practical checklist of routines for safeguarding cultural heritage interiors from climate hazards.

The base for the paper is Norway, where general future climate scenarios include warmer and drier periods (with possibilities of wildfire) as well as wetter periods [6 (p.3)]. There will be an increase in flooding, storm water and avalanches in general, looking at RCP 8,5 in

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[1] This paper will not describe the precise source for each topic, but primary source material from reporting on all meetings and evaluations exists in NIKUs report systems.

[2] ICOM: International Council of Museums, ICOM-CC: International Council of Museums – Committee for Conservation, ICCROM: International Centre for the Study of the Preservation and Restoration of Cultural Property

Norway [7]. It implies the need for preventive measures regarding flooding, precipitation and fire. The checklist is however transferable to any country and heritage interior. Plans for dealing with museum collections are outside of the scope of this paper, but relevant information on interiors is included. Extinguishing systems is a large topic and is also outside the scope of this short paper. Another limitation of the paper is the long-term decay of historic interior caused by climate changes.[3]

2. Relevant Literature

The Council of Europe's report on 'Vulnerability of Cultural Heritage to Climate Change', lists relevant actions by international institutions [8 (p.5)]. Another important document is Safeguarding Cultural Heritage from Natural and Man-Made Disasters by the European Commission [9]. Since these sources gives a relevant overview of the topic on a systemic level, they have a modest focus on practical mitigation measures in order to reduce the consequences of a climate hazard. The work of COST[4] Action C17, "Built Heritage: Fire Loss to Historic Buildings (2002-2006) is, however, indeed relevant. The action's area of interest was objective-oriented and aimed at practical issues [10]. As a follow-up to this COST Action, a set of guidelines was made with focus on low-threshold adaptations [11]. The Getty Conservation Institute (GCI) has in collaboration with ICOM, amongst others, worked on this topic since the 1990's. "The guidelines for museums and other cultural institutions" is a thorough road-map on emergency planning [2].

Guidelines tailored for professionals is also relevant, though not easily available for local management. An example is the work of the International Federation of Library Associations and Institutions (IFLA). They have made a practical manual on Disaster Preparedness and Planning for Professionals [12]. Additionally, the article by Devi and Sharma elaborates on different passive protection measures in heritage museums and libraries [13 (p.4-5)]. They mention different systems of smoke curtains that can be used effectively depending on the building.

However, there are institutions working to reach out to both professionals and non-professionals within cultural heritage. Historic Environment Scotland has worked on heritage buildings and fire prevention by writing Technical Advice Notes and Practitioners Guides in the years 1997-2010. The loss of Fantoft Stave church in a fire in 1992 initiated the financial

[3] For more information on this topic, see amongst others: Lankester, P. (2013). The Impact of Climate Change on Historic Interiors. PhD thesis, University of East Anglia, Great Britain, and Leissner, J. Kilian, R. (eds). (2014). *Climate for Culture, Built Cultural Heritage in times of Climate Change.* European Union Framework Programme, Grant Agreement No. 226973. Leipzig: Fraunhofer MOEZ

[4] COST: European Cooperation in Science and Technology. A European network dedicated to scientific collaboration.

possibility for the Directorate for Cultural Heritage in Norway to work on fire prevention, protection and safeguarding of the Stave churches. The work intensified the Directorate's awareness regarding fire risk and placed fire protection higher up on the agenda for protection of built heritage in Norway. The Swedish National Heritage Board work on the topic has, among others, resulted in the Handbook in Emergency Planning and Salvage Rescuing [14]. English Heritage and London Fire Brigade cooperate to reach out to owners and managers of historical buildings. They have made multiple workings sheets easily available on the Internet [15]. Here, they state that procedures for salvage will vary according to the scale of the incident, but it is a worthwhile exercise to plan for the worst-case scenario i.e. the removal of all the objects. Damage control is also a key factor which should be fully considered, and ceiling artwork with the risk of being damaged by fire, smoke or water is specifically mentioned [16 (p.11)]. Another example of low-threshold mitigation measure is the use of tarpaulin or similar for protection in situ if a priority object is too heavy or too large to remove [17 (p.28)]. But how to go on from this? Seldom does the literature answer these complex matters thoroughly, and in such matter states the gap between international manuals and needed information at a local level.

3. Results

The already mentioned guides and manuals provide a walk-through on prevention, risks, preparedness, response and recovery at different levels. On the preparedness level there is a predominance of instructions for systems and plans. Apart from Guideline No 30 by COST Action C17 and work done by Historical Scotland and English Heritage/LFB, most of the other literature in its present state is most suitable for medium to large museum management, and not small countryside museums, old houses, mansions or castles open to the public, churches, or buildings owned by The National Trust, among other examples. The checklist below (Table 1) will supplement GCI's guidelines' chapter three, that deals with emergency preparedness in steps 1-7 [2 (p.53-76)]. Chapter three presents the steps 1) assessing the hazards, 2) identify assets and vulnerabilities, 3) implement preventive measures, 4) implement preparedness measures, 5) develop the response plan, 6) develop recovery procedures and 7) write the emergency plan. The presented checklist supplements the work within step two and three in GCI's topics on emergency preparedness.

Table 6. Checklist for safeguarding historic interior

Overall	What are the local climate projections? Orient yourself to the hazards of your building on regional and local levels. Link this to your county's disaster risk reduction plans. Discuss possible prevention systems and direct alarm to the fire brigade that shows which zone that has been triggered.
Information	Is the interior painted or does it have wall tapestry? Collect information about materials and the history of the decorated surfaces. It might be water sensitive. It will be the base for finding appropriate measures. Does the interior have decorated ceilings? There might be challenges such as the fire brigade needing to use the roof in order to let out smoke and rig for the fire hoses. Covering and evacuation will need to focus on decorated walls and inventory pieces. Document the painted wall ceilings well with high quality photographs and thorough description of material, technique and motif.
Rooms and zones	Are there any zones that have a large concentration of valuable items or interior? Make priority zones where the fire brigade attempts to prevent a fire from evolving. Maximum three items in each zone of the building [17 (p.27)]. If large rooms have priority zones with interior or inventory, fire curtains can function as compartmentation [13 (p.5)]. Inform the local fire brigade if you have a cellar or a room underneath the ground floor (especially in churches) with valuable items or important cultural heritage objects. The information is crucial if there is a flood or a water leakage.
Dismantling	Can a part of the interior be dismantled? How? Invite the local firemen and a conservator or another expert on art, construction and materials if uncertain. Describe how to dismantle in an emergency rescue plan. How to dismantle large items mantled to the wall/floor: Describe how to dismantle a large piece with appropriate equipment and tools. Are some parts more important than others so it can be parted if needed?
Placement	Is the item placed safe from theft, and in addition, possible to be dismantled or carried out? Look at types of screws and mantling systems that the fire brigade can handle during an emergency. If the room already has fire suppression systems, think of the optimal placement of the items to allow optimal coverage from water damages [18]. If you have a safe with valuable items, check the resistance time according to the run time for the fire brigade. Inform about the need for cooling of the safe in the emergency rescue plan. Mantle valuable items at a distance from windows or outer walls that risk leakage.
Equipment and storage	Store large tarpaulin covers in case of evacuation and covering for minimize water damages. Make sure you know where to place large parts of the interior after dismantling. This may be a barn owned by the neighbour, get a truck or a container etc. If objects cannot be dismantled there are fire blankets available in different sizes that block radiant heat and soot particles. Make an overview of which items need coverings and define what the cover should protect from. Buy necessary equipment.
Make an emergency response plan	Above mentioned issues need to be discussed in interdisciplinary groups. Create an opportunity for dialogue with the local fire brigade and heritage experts. Go through the building discussing different scenarios. Discuss items and interior – what are the possibilities and limitations?

4. Conclusion

There are many manuals and guidelines for emergency response in cases of built cultural heritage. They should be refined and prepared and become easy working documents on a local level for management without cultural heritage expertise. Important undertaken work like the COST Action C17, Historic Environment Scotland and LFB together with English Heritage needs to be conveyed across borders so owners and managers of smaller cultural heritage buildings and institutions have access to them. One should strive for closer cooperation between the fire brigade and cultural heritage experts. Relevant information on climate hazards and preventive measures should become available for owners and managers of cultural heritage buildings.

There is a lack of detailed information on how to deal with historic interiors both in the existing emergency preparedness plans and the salvage rescuing and mitigation. When it comes to climate and their impact on historical interior, much is written about the slow degradation and damages. How to avoid or minimise the impact and following catastrophic damages from sudden climate hazards seems to be a forgotten theme. The reason might be the lack of connection between international and local levels. This paper has presented a practical checklist of routines for safeguarding cultural heritage, focusing on the interiors, from fire and climate hazards. Hopefully, it will contribute to raise the awareness of which low-threshold preventive improvements to implement to save cultural heritage interiors. There is, however, a clear need for more research on specific practical solutions, testing and knowledge-sharing when working with mitigation and consequence-reducing measures on a local level. We have a job to do; this should become future projects.

5. Acknowledgements

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How can conservation management plans for cultural heritage play a role as a tool for climate adaption?

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Abstract

This paper will discuss how buildings with significant cultural values can become more resilient to the ongoing climate changes. It suggests that conservation management plans can be used as tools for climate change adaptation and sustainable management. It will describe the results from a feasibility study on value-based conservation management plans for culturally valuable buildings carried out by the Swedish National Heritage Board in cooperation with the University of Uppsala and guest professor Derek Worthing. The conclusions from the feasibility study were incorporated into a web-based guideline describing a process when writing conservation management plans. This guideline describes the different steps that should be considered when making a tool for conservation management plans. It enhances the importance of working with risk and vulnerability assessment and with standards as methods in order to identify how a building and its values may be vulnerable to different risks regarding the impact of climate change.

Keywords – Climate adaptation; management tools; conservation management plans; vulnerability assessment; planned and sustainable management.

1. Introduction

1.1 Background

Ongoing climate-changes and extreme weather conditions around the globe pose serious threats – not only towards humanity but also towards the conservation of cultural (built) heritage. Increasing climate awareness, along with an international strive towards sustainable and economic use of natural resources, involves new challenges for the way we maintain our built heritage today.

We argue that a well-kept property with a conservation management plan based on a risk assessment stands a better chance to meet many different risk scenarios that climate change might cause in the future. Preparing a conservation management plan demands many resources and is expensive initially, but when such a plan is well prepared and tailored for the building; it is a sustainable investment and will pay back its cost in the long perspective.

How can conservation management plans and sustainable maintenance be connected? They could be connected through working towards both short-terms and long-term goals (a perspective that is more than 5-7 years) and with resource management. Long-term goals require not only planning but also perseverance – the goals need to be kept even when resources periodically prove to be limited or decreased.

One of the European standards for the conservation of cultural heritage (EN 15898:2019 Conservation of cultural heritage – main general terms and definitions) defines maintenance as: “periodic preventive conservation actions aimed at sustaining an object in an appropriate condition to retain its significance.” At the Swedish national heritage board, we define sustainable maintenance as maintenance that is planned and has a focus on preventive actions. Building materials life expectancy can be prolonged by regular maintenance. Well-kept materials and buildings can withstand extreme weather events.

1.2 Challenges

Historically, locally produced buildings materials have been used for most of the listed buildings we have today. Sustainability entails avoiding depletion of natural resources. The materials chosen for rebuilding or maintaining a building should be easy to maintain, repair and reuse, and not encourage excessive consumption and this could be stated in the conservation management plan.

Risk and vulnerability assessment and preventive and planned maintenance are crucial steps to obtain preparedness for all kinds of slow, rapid or cumulative damages that might appear on a building. With ongoing climate changes, it is more important than ever to have frequent and regular periods for supervision, inspection and maintenance of a property or a building.

The damages caused by the ongoing climate change are not new types of damages, but we expect them to appear more often than they did during the 20th century; and appear in new geographical areas of Sweden [1, 2]. In addition, the damages can be of a larger scale than we have experienced before. This will make it even more important that the property owners or users have done risk and vulnerability assessments and are prepared for experiencing damages that they have never dealt with before.

The damages can be rapid (for example, fire, flooding, or landslides), slow (for example mould, salts, or insects), or cumulative (small but many changes that often are unnoticed in the beginning.) The latter are often caused by humans, for example caused of lack of maintenance or application of the wrong type of maintenance. Alternatively, cumulative damages can be caused by the lack of communication between different professionals when they have carried out measures or work with conflicting objectives). Dramatic, rapid events that occur more seldom but have a large impact in one single occasion, were more often thought about and taken in count.

Remedial conservation that is done when the damage already has occurred, could pose a threat to the building’s cultural significance, since repair is then often executed in a sort of reactive “panic mood”. In addition, such measures are often done without consulting other professions or the users of the property, because there is a need to act fast.

1.3 Preparing for the future

While working with the Swedish National Heritage boards climate adaptation plan for cultural heritage, one of the observations was that a building with a conservation management plan and planned preventative maintenance, appeared to have a greater chance of coping with climate caused stress. When everyone involved in the management, is prepared for several possible different scenarios and when the cultural values are identified and known in the organisation, everyone knows what they are protecting and how to protect it.

In 2015, The Swedish National Heritage Board decided to carry out a feasibility study to verify the observation and to map the use of different models of conservation management plans in Sweden. For comparison, the working group also looked at international examples of conservation management plans and guidelines from UNESCO, Great Britain and Australia. The feasibility study identified both success factors and deficiencies in the drafting and implementation of conservation management plans in Sweden.

2. Methodology

Sample feasibility study mapped the present use of different models of conservation management plans used by some organisations in Sweden, and which described the current knowledge situation and the needs of future research. Focus was on buildings with cultural values or listed buildings. The study was carried out through:

- Review of national and international literature and of guidance documents.
- Interviews with property managers in the field of cultural heritage employed either by the state (governmental authorities or county boards) or by municipal museums.
- Review of selected examples of different models, tools and guidelines for management available in Sweden (like conservation management plans for ruins and for listed buildings, both private owned and owned by the state, conservation management plans for local folk museums or open-air museums).
- International outlook done by Derek Worthing, visiting researcher at Uppsala University. He also interviewed some major property managers at government agencies as well as major organisations in the UK. He also contributed to the study with international literature and international examples of conservation management plans [3].
- Investigating how much governmental funding or cultural heritage grants that were given to different management tools.
- Organising a workshop for the county administrative boards discussing the use and funding of conservation management plans.

3. Presentation and Discussion of Results

Several guidelines and international charters give advice on what a conservation management plan could include [4]. Two important steps in the preparation of a conservation plan is both to identify how the significance of a building is vulnerable, and to set out policies for retaining that significance in the future. However, very few of the guidelines that were studied in 2015, gave advice or methods on how to do that.

3.1 Identified Deficiencies

Some identified deficiencies that appeared more common than others in the studied conservation management plans were:

- The conservation management plans were often made by external consultants and had usually only one competence or profession involved.
- There was very often a larger focus on the history of the building in the conservation management plans, than on how to maintain the building or how to safeguard it´s significance.
- There was often a confusion about terms and definitions for different management tools.
- There was often no description of the decisions or priorities among actions and how they were chosen.
- The conservation management plans were seldom implemented or disseminated among the different users or stakeholders.

In addition, the review of the conservation management plans showed that all of them lacked:

- Risk and vulnerability assessment.
- Climate change awareness.
- Connection to budget, resources or other tools for management.
- Recommendations on when and how to evaluate the conservation management plans.

3.2 Success Factor

The feasibility study showed that to become more successful and used, the conservation management tool needed to:

- Be realistic (and not describe an ideal but never reached situation of resources, of money and staff.) It should be based on the resources that one has when the plan is written.
- Engage or encourage cross-sectoral collaboration between several competencies and professions to avoid that only one perspective is thought upon.
- Include participation not only with representatives from the facility owners but also from everyone that is going to use the property on a daily basis or those that are going to take part in the daily maintenance

- The cultural significance of the property needs to be identified, described and knowledge about it established and implemented in the whole organisation.
- Threats and vulnerabilities, both to the building itself and in the organisation, who maintain or use the property, need to be identified and addressed.
- The conservation management plan should be done with clear and easy to follow up goals.
- The goals should be implemented in all documents that are part of the conservation maintenance plan, both in documents with short-term goals and in documents with long-term goals.
- Include regular follow up and revision.

4. Conclusion

A conclusion from both the study (and from the Swedish National Heritage Boards ongoing work with a climate action plan), is that a conservation management plan can be used as an effective tool for meeting the effects of ongoing climate change. With a conservation management plan that includes risk and vulnerability assessment, and with planned preventative maintenance that is anchored among owners, managers and users, a building has a greater chance of coping with climate caused stress. A success factor is when everyone involved in the management and use of the building, are mentally prepared on several possible different future scenarios, and they are aware of what cultural values they should protect. Preventive and planned measures makes it possible to distribute costs on several budget years. (A large, unplanned damage often causes large economic problems and the regular maintenance might be suffering.)

The results from the feasibility study showed that there was a need for more knowledge on how to improve the conservation management tool to make them more successful and used than they were. There was also a need for explaining different terms for property management, and to show collected good examples of conservation management plans. The knowledge from analysing the feasibility study is now used in a web-based guideline on the Swedish National Heritage Board webpage, describing a process that can be used when writing conservation management plans [5]. It describes different steps that can be considered when making conservation management plans. The guidelines enhance the importance of working with risk and vulnerability assessment and with CEN-standards in order to identify how a building and its cultural heritage values/significance may be vulnerable to different risks regarding the impact of climate change.

Something that become very clear is the need of a risk assessment tool or guideline that are tailored especially for built heritage. We need not only a simple method but also digital management systems that are adapted for maintenance of listed buildings or for buildings with cultural values.

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Two nations, one approach: Establishing joint-nation coastal and maritime baseline data for future resilience planning; the CHERISH Project

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Abstract

The EU-funded Ireland-Wales CHERISH Project, examining climate change and coastal heritage in Wales and Ireland, began in 2017 and will run until 2022. This paper will discuss the joint-nation, cross-disciplinary approach developed within CHERISH as a model which enables efficient development of working practices to document baseline change at some of the most important coastal, island and maritime heritage sites threatened by climate change. Only with two nations working actively together as a single survey team, sharing technical and methodological approaches, can a unified response to shared climate change impacts be developed and deployed. This paper will look at case studies in Wales and Ireland where the single team, joint-nation approach has been employed to best effect.

Keywords – Climate change; coastal heritage; remote sensing; Ireland-Wales; archaeology

1. Forging the Single, Joint Nation Team

Establishing meaningful collaborations between organisations can be challenging in today's economic climate. Building, maintaining and making those collaborations work in the longer-term is where the real work begins, particularly if organisations involved have very different functions and roles. How then does one ensure staff in four organisations across two countries, separated by the Irish Sea, work as a single survey team to a common purpose?

The CHERISH Project (an acronym for 'Climate, Heritage and Environments of Reefs, Islands and Headlands') was forged as an ambitious cross-disciplinary project during more than two years of business planning between late 2014 and its launch in early 2017. It is funded by the European Ireland Wales 2014-2020 programme. It partners terrestrial archaeologists and remote-sensing practitioners (in the Royal Commission and the Discovery Programme, Ireland) with geographers, geomorphologists, luminescence specialists and earth scientists in

Aberystwyth University and marine surveyors and geologists in the Geological Survey of Ireland. At the outset it aimed to address the heritage of poorly-surveyed and data-poor stretches of rural coastline and seascapes, uniting the study of terrestrial and maritime heritage sites in designated survey areas, as well as eliminating the 'white ribbon zone' or data-poor region between high and low water (Driver and Hunt 2018). This was a challenge. The coastlines of Wales and Ireland are where multiple interests converge from existing or recently-ended heritage recording programmes like *Arfordir* (*'Coast'*) in Wales, to ongoing climate change risk assessments for historic places and properties by national agencies like the Office of Public Works, National Monuments Service, Cadw and the National Trust and government-level strategies focussing on coastal defences and infrastructure.

The CHERISH Project mainstreams the following principles in all its work:

A joint nation approach: There are huge synergies in the shared coastal heritage of Ireland and Wales; two nations across a single seaway with a common heritage of coastal earthworks, historic structures and wrecks with paleoenvironmental potential locked in coastal dune sites, lagoons and wetlands. This common heritage raises shared concerns over the impact of climate change and increased storminess, requiring a common approach to recording change and common recording principles (Figure 2).

A single Survey Team: A joint-nation approach is embedded in all CHERISH work. Staff among the four partner organisations are part of a single CHERISH Survey Team, strengthened by joint-nation training events and fieldwork where ideas and working practices can be shared and improved. Maritime specialists, archaeologists and geographers work together towards a defined set of common goals, a strong model going forward.

Fixing the baselines; the Toolkit Approach: Using this approach, CHERISH is establishing accurate baseline data at our terrestrial and maritime study sites to allow change to be exactly measured. Recording methods range from aerial survey and photogrammetry using aircraft and Unmanned Aerial Vehicles (UAVs) coupled with laser scanning and detailed survey, to geophysics, excavation and laboratory analysis of peat cores and luminescence samples to date past storm events and environmental change. CHERISH bench-tests and evaluates different approaches as part of its toolkit approach (Figure 10), securely archiving resulting data for long-term benefit.

CHERISH

Newid Hinsawdd a Threftadaeth yr Arfordir
Climate Change and Coastal Heritage
Athrú Aeráide agus Oidhreacht Chultúrtha

Figure 8 The CHERISH logo, designed by Ian McCarthy of the Discovery Programme, encapsulates the ethos of the project. It is trilingual, mainstreaming Welsh and Irish as does the entire project. The protective shield comprises the green of Ireland and the red of Wales. Inside, the terrestrial coastal heritage of a castle tower stands above the sea, backed by representations of landscape and wildlife (CHERISH Project)

2. A joint nation approach:

A unique strength in the Ireland-Wales 2014-2020 European Territorial Co-operation (ETC) programme for projects based around climate change and cultural heritage was the recognition at the outset of shared values; both nations have common cultural heritage site types as well as inescapable geographic links in terms of climate change risks, particularly from increasing storminess in the Irish Sea zone.

A joint nation approach was instilled at Business Planning stage. The CHERISH Project (Business Plan, Delivery 2.5; cited in the CHERISH Executive summary 2017) pledged to:

> *'..implement a cross-disciplinary, cross-border Survey Team linking land and sea that brings together partners who are leading specialists in a variety of fields – climate change, hydrography, geology, archaeology built and maritime heritage, remote sensing, environmental science, storminess and scientific dating.'*

In addition, the Business Plan (Strategic Fit 1.1) stressed the huge value to be gained in working more closely together;

> *'This is an unparalleled opportunity for both nations to gather shared data and new cultural heritage information across the Programme area'*

Joint working across two nations does not happen automatically. CHERISH maintains a regular programme of monthly all-partner meetings, 6 monthly face-to-face partner meetings in Ireland or Wales and annual face to face meetings with our Advisory Panel. Files are shared via Basecamp or OneDrive. A range of project deliverables for all partners include training events, professional seminars and engagement events and joint-nation fieldwork weeks in different parts of the programme area. For example, the project has nine CHERISH Initiatives (CHERISH Executive Summary 2017, 9), the first (CI-1) being 'CHERISH survey teams developing joint best-practice guidance: Integrated joint-nation teams employed to survey and record heritage sites threatened by climate change in targeted coastal communities…' (CHERISH Annex C).

3. A single survey team; inter-disciplinary approaches to recording heritage sites

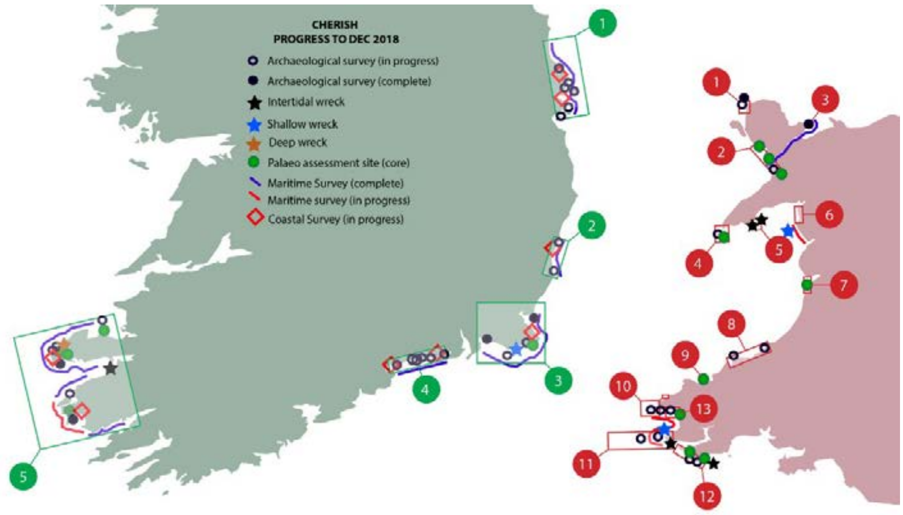

Figure 9 A typical cross-disciplinary progress map from Year 2 reporting upon completed – and complementary - archaeological surveys, maritime surveys and palaeoenvironmental assessments across the joint-nation survey area (Crown Copyright: CHERISH Project).

Early in the business planning for the EU-funded CHERISH Project we recognised that the only way to ensure four very different organisations in two nations worked successfully together was to embed the ethos of a *single joint-nation survey team* in the project from the very beginning. This four-way partnership, which continues to strengthen, delivers enormous benefits to the organisations involved in terms of joint training, information sharing, developing inter-disciplinary work practices; these benefits are, in due course, shared with the wider network of professional and community stakeholders and policy makers. In this way the best skills can be deployed to measure impacts and gather baselines at some of the most important coastal, island and maritime heritage sites threatened by climate change.

In practice this means that whether a member of staff from the CHERISH Project is surveying a promontory fort in Pembrokeshire, coring a wetland in Kerry or onboard the survey vessel RV Keary in Dublin Bay, they are working as part of a single CHERISH Survey Team deployed across both nations. This single CHERISH Survey Team is multidisciplinary. Archaeologists frequently work alongside geographers (Figure 8) and maritime specialists with an approach which is immediately stronger and more productive for documenting the coastal and maritime environment than a traditional single-subject approach to recording.

3.1 The shared coastal heritage of Wales and Ireland

There is an immense shared heritage across the Irish Sea zone (Figures 3 & 4). From the west-facing coasts of Wales, and the east, south and south-western coasts of Ireland in the convergence area, there are classes of heritage site familiar across the seaways. Prehistoric and early medieval coastal promontory forts frequently suffer from coastal erosion and cliff collapse with a consequent loss of unexcavated data (Figures 3, 5 & 6). Medieval chapels, churches and religious sites are survivors in the coastal zone from the pioneering establishments of the early seagoing saints; study sites on remote islands include Illauntanig religious settlement in County Kerry (CHERISH 2018, 12-3) and the monastery of Priestholm on Puffin Island or Ynys Seiriol (Figure 12), in north Wales. Castles and mottes from the middle ages were often built close to ports, or in defensive coastal positions, like the CHERISH baseline study site of Glascarrig Motte in Wexford where recent geophysical surveys are extending our knowledge of a buried township threatened by coastal erosion. Where there are differences between the archaeological monuments of each nation there are opportunities for shared learning. Irish promontory forts are commonly thought to be early medieval in date, whereas those in Wales normally date to Iron Age and Roman times.

Figure 10 Shared coastal heritage: eroding coastal promontory forts and islets with prehistoric and early medieval characteristics in Ireland and Wales. (left) Woodstown promontory fort, Annestown, Co. Waterford; (right) Sheep Island, South Pembrokeshire (Crown Copyright: CHERISH Project).

In recent centuries rural coastlines saw an expansion in a range of shared site types, among them shipbuilding yards, docks, wharfs, limekilns and other structures linked to coastal trade and shipping. The linked study of shipwrecks is an area where national boundaries blur; the baseline monitoring wreck of the Albion paddlesteamer, beached in Pembrokeshire, was a Bristol ship returning from a regular trade run to Dublin. The wreck of the SS Manchester Merchant in Dingle Bay (CHERISH 2020, 4), under study for CHERISH by the GSI and Discovery Programme, was en-route from New Orleans to Manchester when it sunk, a truly transnational maritime heritage site; both shipwrecks recorded no loss of life.

Figure 11. Baseline aerial survey over similar historic coastal resort towns with sand bars, coastal dune systems and inland lagoons in Wales and Ireland (Left) Tywyn, Gwynedd and (right) Tramore, Co. Waterford (Crown Copyright: CHERISH Project).

3.2 Interdisciplinary approaches to documenting climate change impacts: Dinas Dinlle

Climate change impacts are best documented at a joint-nation level. One example is the recognition of the severe effects that increased ground-water resulting from more intense rain storms is having on eroding the cliff faces at two similar coastal promontory forts where baseline studies are underway: Dunbeg in south-west Ireland (CHERISH 2018, 22-24) and Dinas Dinlle in north Wales. Both of these spectacularly eroding coastal forts have previously been used to illustrate the principles of extreme coastal erosion, and both have suffered recent catastrophic cliff collapses which have been documented by CHERISH (Figures 5 & 6). Indeed it would be difficult to study the formation, history and erosion of these sites without the involvement of specialists from disciplines other than archaeology.

Figure 12 Dinas Dinlle. UAV images showing the cliff-face before and after the collapse in early 2019. Before collapse: 11 June 2018 (Crown Copyright: CHERISH Project)

Figure 13 Dinas Dinlle. UAV images showing the cliff-face before and after the collapse in early 2019. This image taken after the collapse on 14 Feb 2019 revealed what appeared to be the clear edge / cut of the inner ditch and a previously unreported fill of sand (after Hunt et al. 2020, Figs. 9-10; Crown Copyright: CHERISH Project).

Between the 3-7 June 2019 the combined CHERISH team comprising archaeologists and geographers from the Royal Commission and Aberystwyth University undertook cliff-face investigations of archaeological and glacial deposits visible along the top of the eroding cliff-face of Dinas Dinlle coastal fort in north-west Gwynedd, and a core transect across its southern defences (Hunt *et al.,* 2020). These investigations formed part of wider archaeological and palaeoenvironmental investigations at Dinas Dinlle undertaken since 2017 by CHERISH. At such a heavily protected and designated coastal fort, the work took place with the full permission from the landowner, the National Trust, and with Scheduled Monument and Site of Special Scientific Interest (SSSI) consents from Cadw and Natural Resources Wales (NRW) respectively.

The investigation area was located towards the top of the cliff and comprised a 13m wide and maximum 4m deep section of vertical cliff-face. The best way to access the unstable sand and gravel cliff was via rope and harness (Figure 8). To enable the team to work in these challenging conditions they first participated in a two-day safe working at height course before employing Plas y Brenin outdoor centre in Snowdonia to supervise the rope work on site. Hand excavation by archaeologists allowed deposits to be carefully recorded, while the presence of geographers allowed the geomorphology of the cliff to be closely examined and sampled. Overlapping UAV imagery was captured to produce a Structure from Motion (SfM) 3D reconstruction and orthomosaic of the site for archiving. Five samples were also taken through the profile of the ditch from contexts for Optically Stimulated Luminescence (OSL) dating by Professor Helen Roberts (see Figure 9). The cliff-face investigation was augmented by a simultaneous core-transect of the hillfort's southern defences (Figure 7). The firm dry sediments of Dinas Dinlle are too compacted to be sampled with a hand-driven Russian or Livingstone corer, therefore an Atlas Copco Cobra percussion corer was employed. The Cobra uses a petrol driven engine to produce compressed air to hammer a 1m core barrel into the ground. The core is retrieved using a manual jacking system.

Figure 14 **Hywel Griffiths and Sarah Davies coring through the southern outer rampart (Crown Copyright: CHERISH Project).**

The investigations enabled more detailed analysis of erosion affecting the site. These comprise a variety of pressures including exposure to strong winds and rain from the sea which erode the softer sand sediments and leave behind a scoured 'shelf' or surface at the junction with the harder glacial sediments. Removal of the sand, which is also exacerbated by avian and mammal activity, then causes the overlying turf to slump and degrade. Rain is another pressure as water infiltrating the surface of the fort interior passes easily through the sand units but is restricted by the dense nature of the underlying glacial sediments. When saturated, particularly following periods of more intense rainfall, the water emerges from the cliff-face at the interface between the soft and hard sediments which promotes gravitational slumping and degradation of the softer sediments (Figure 6).

As with Dunbeg in Ireland it is the action of groundwater pushing off the cliff face from within, following periods of intense rainfall, which have caused at least some of the most extreme cliff erosion at these sites rather than wave action from the sea. The multidisciplinary team approach to work at Dinas Dinlle was the only way to study archaeological and geomorphological processes together; the presence of team members who have analysed similar sites and processes in Ireland has allowed specialists to compare scientific data in both nations.

The findings of this initial investigation contributed to the highly successful evaluation excavation which were held at Dinas Dinlle during the summer of 2019, managed by the Gwynedd Archaeological Trust for the CHERISH Project. Among other findings, the excavations demonstrated the preservation of very high quality stone round houses within the fort buried by a deep deposit of windblown sand, apparent evidence that settlement in parts of the fort at least was curtailed by the effects of catastrophic storms (Lynes *et al.* 2019). The final report is still in preparation.

Figure 15 Using rope-access to investigate the silted ditch of Dinas Dinlle coastal promontory fort, Gwynedd, 2019. Geographers and archaeologists worked side by side in the excavation, allowing analysis both of archaeological deposits and also geomorphological and glacial processes revealed in section (Crown Copyright: CHERISH Project).

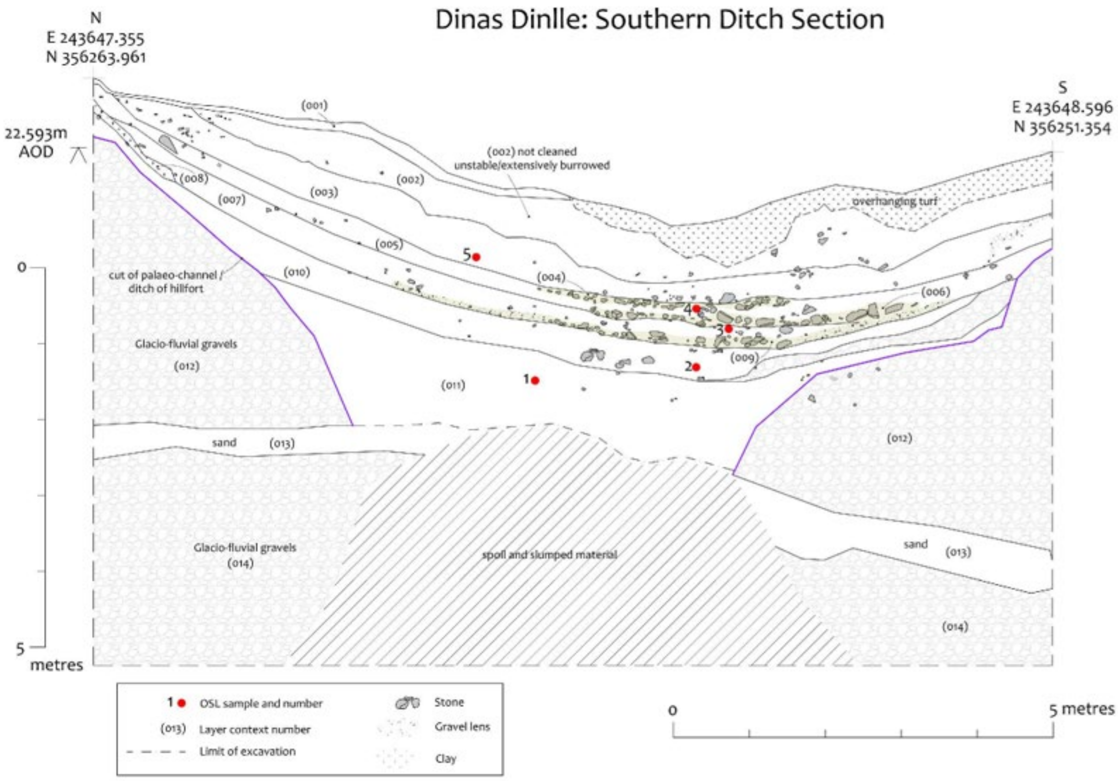

Figure 16 Using rope-access to investigate the silted ditch of Dinas Dinlle coastal promontory fort, Gwynedd, 2019. The drawing shows the position of luminescence samples obtained for dating (in red), an essential scientific process for a ditch section which produced no charcoal nor datable artefacts (after Hunt et al. 2020, Fig. 14; Crown Copyright: CHERISH Project).

4. Fixing baselines at the coast edge; the toolkit approach

Early in the project planning stage we aspired to deploy a diverse ‘toolkit’ approach to recording the coast edge, allowing us to bench-test a wide range of survey and sampling techniques while also tackling the landscape at micro and macro levels with a multidisciplinary team. From the project start we promoted this through a basic cartoon of the ‘Toolkit approach’ in newsletters and lectures; this was recently brought up to date as part of a range of inspiring new professional illustrations for CHERISH by Carys Tait (Figure 10).

The toolkit diagram illustrates the principles of the approach for archaeological recording. Higher level non-destructive remote sensing (RS) by airborne LiDAR, satellite and aerial photography informs lower level RS techniques including UAV survey and geophysics, contributing further detail to terrestrial and marine survey. Excavation, whether on land or underwater, along with coring and sampling, are the ultimate micro-level scientific investigations of our eroding and threatened coastal heritage. Data resolution ranges from microscopic analysis of pollen grains and diatoms from wetland and coast-edge cores, through to millimetre accurate laser scanning technologies, and upwards to centimetre accurate UAV photogrammetry to 25cm resolution airborne LiDAR.

From our original aspirations in the planning stage, it is heartening that every aspect of this diagram has so far been employed on multiple occasions within the CHERISH Project, often with repeated surveys of baseline study sites.

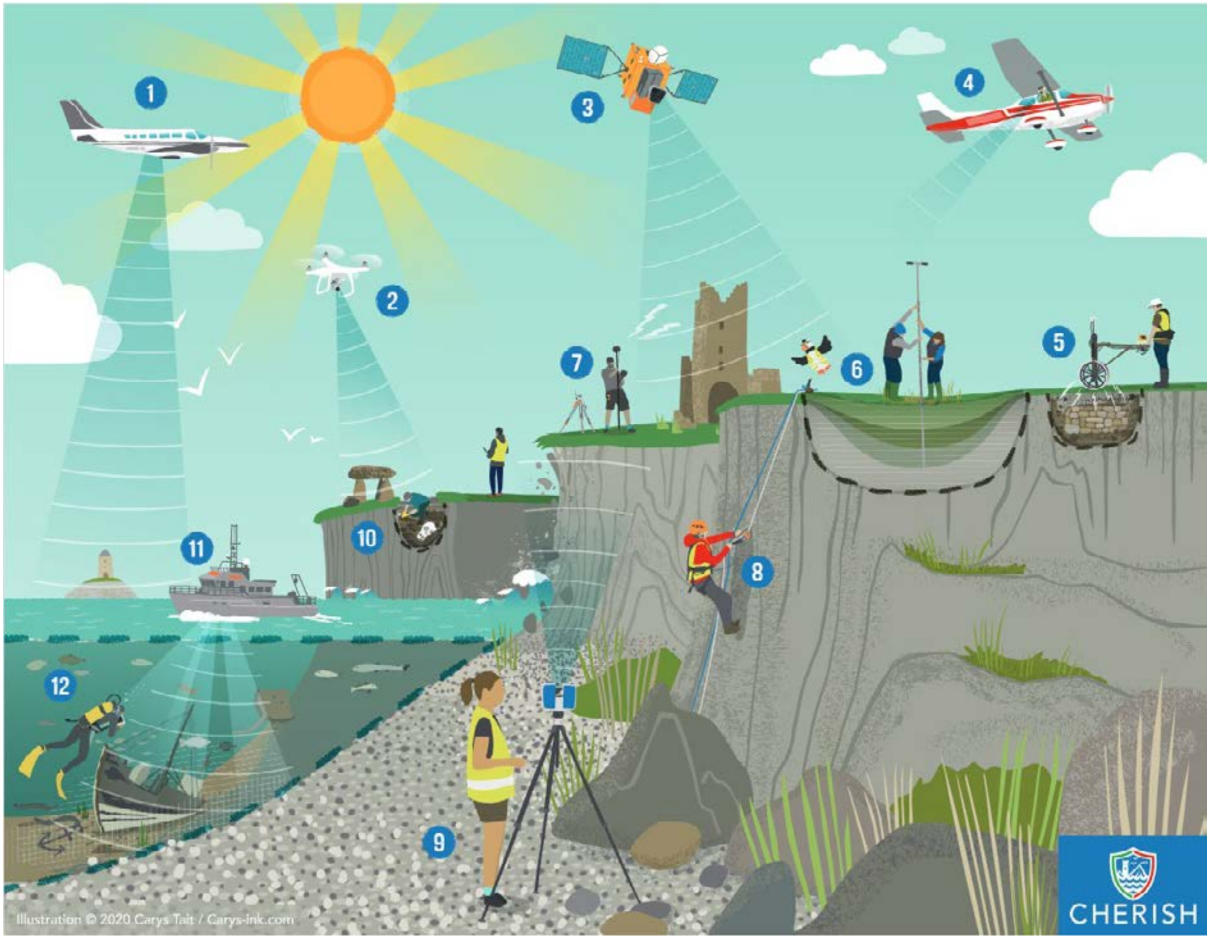

Figure 17 The CHERISH toolkit approach to surveying coastal and maritime heritage sites in Ireland and Wales, including coverage of the 'white ribbon' zone between high and low water; a new graphic by Carys Tait 2020. To date all of the technologies and approaches shown here have been deployed within the project; certain project personnel are also recognisable! Numbers relate to a published key in the travelling exhibition (© Carys-Ink. © CHERISH Project).

How does the toolkit approach work in practice? This is best illustrated with the case study of Puffin Island or Ynys Seiriol, a privately-owned island situated 0.8 km off the Isle of Anglesey ('Ynys Môn) in north Wales (CHERISH 2019, 12-13; Driver *et al.* 2020). It is composed of Carboniferous Limestone, rising to 58m OD. Cliffs form its south-eastern margin, sloping gradually to the north-western side of the island, with lower, isolated cliffs located. Puffin Island is a Special Protected Area (SPA) and site of special Scientific Interest (SSSI) for its cormorants. The island is home to the early medieval monastery of Preistholm and a twelfth century priory church, which sit at the heart of a landscape of field systems and enclosures.

Although scheduled and well preserved, the archaeological structures are badly overgrown with alder woodland and scrub vegetation rendering them difficult of access.

The island was flown with 0.25m LiDAR at low tide in 2017 by Bluesky International for CHERISH (Driver and Hunt 2018), providing a highly detailed Digital Surface Model (DSM) but also allowing for a vegetation-stripped Digital Terrain Model (DTM) which revealed landscape-scale features. In June 2018 the CHERISH Team from the Royal Commission visited with Cadw staff to laser scan the ruins of the church, following some permitted clearance of the undergrowth, which captured all required detail except for the church roof. The team returned in November of the same year to carry out UAV photogrammetry to infill the roof top and other inaccessible details for the 3D model (Figure 11).

Linked to this terrestrial work, the Geological Survey of Ireland undertook marine mapping of the seabed around Puffin Island in 2018 providing an up to date assessment of inshore shipwrecks whilst allowing a seamless onshore/offshore 3D map to be made of Puffin Island for the first time (Figure 12), linking the terrestrial LiDAR and offshore multibeam bathymetry collected as part of the CHERISH project (Craven and Barry 2019). Overall, there is extremely good correlation of the two data sets, with the generation of a continuous map. Overlap of the two datasets containing a true measure of land/seabed surface was small (416m^2), with a mean difference of 0.11 ± 0.58 m between the two data sets.

Figure 18 Puffin Island. Photogrammetric model of the twelfth century church tower seen from the north-east; dense point cloud produced using Agisoft metashape from 186 photographs flown by a UAV (Crown Copyright: CHERISH Project).

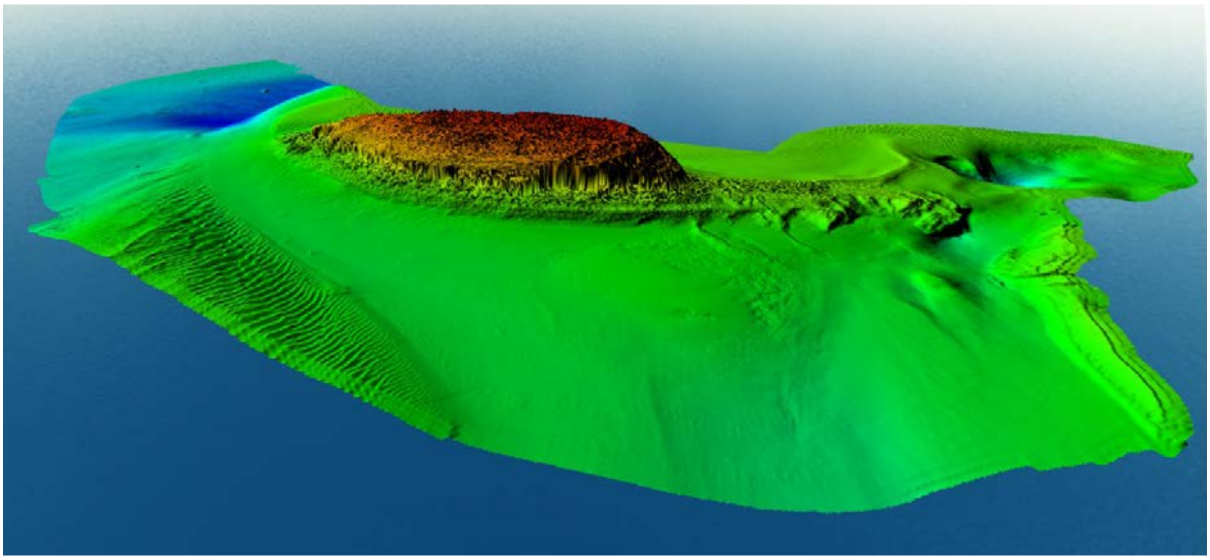

Figure 19 Puffin Island from the north: 3D image of seamless onshore/offshore map produced in Global Mapper (Copyright: Geological Survey of Ireland and CHERISH Project

5. Conclusions

This paper has demonstrated the shared themes which exist in the coastal heritage of Wales and Ireland. There are shared problems in the quality and availability of geomatic data in remote or peripheral stretches of rural coastline and islands, which are conversely rich in heritage but data poor. This, coupled with the increasing pressures and threats brought about by our changing climates (e.g. HEG 2020), mean that unified and coordinated approaches to recording heritage sites together with efficient dissemination of results and long-term archiving of data are more important than ever before.

The joint nation approach presents huge opportunities. With CHERISH a strong way of working between four very different but highly skilled organisations have been developed and has begun to achieve tangible results through the deployment of a single survey team across two nations. These results now need to inform future climate change and coastal adaptation strategies to build resilience. As part of the original Business Planning stage for CHERISH, 8 Ultimate Changes were identified to be delivered by the project funding (CHERISH Executive Summary 2017, 10). These included (2), 'Improved evidence base for statutory protection, decision-making and adaptation strategies' and (6), 'New joint-nation best practice guidance'. To these ends the newly-published *Historic Environment and Climate Change Sector Adaptation Plan* for Wales (HEG 2020) includes key case studies and data from CHERISH (pp. 20, 29) while best practice guidance is now in development. Only through efficient collaboration between universities, government departments, agencies and decision makers will the future challenges of a changing climate be tackled head on.

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Session 6: Maritime cultural heritage in a changing climate

Session chair

Philip Robertson, Historic Environment Scotland, Scotland

Presentations

CHERISH: Climate change impacts on a maritime cultural landscape, Ballinskelligs Bay, County Kerry

Sandra Henry, Discovery Programme, Ireland

Greenland's wild west: Cruise ships, climate change and threats to heritage sites

Hans. H. Harmsen, Greenland National Museum and Archives / National Museum of Denmark, Greenland

The effects of climate change on coastal heritage sites located on the south-west coast of Ireland

Fergus McCormick, Office of Public Works

A Climate Vulnerability Index for World Heritage: Assessing climate change risks at the Heart of Neolithic Orkney

Alice Lyall, Historic Environment Scotland

CHERISH: Climate change impacts on a maritime cultural landscape, Ballinskelligs Bay, County Kerry

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Abstract

This paper details the ongoing work of the EU- funded Ireland-Wales CHERISH project to gather information on climate change impacts on the maritime cultural landscape of Ballinskelligs Bay, County Kerry. The paper discusses the different survey techniques utilized by the CHERISH team to create measured datasets, paleo-environmental and archaeological site records. The various survey techniques mapped the significant heritage assets located along this exposed bay and gathered both qualitative and quantitative data to enhance the Sites and Monuments Record and to inform on climate change impacts occurring within the Bay. The fieldwork comprised both site targeted and larger survey areas forming a baseline dataset from which to map future climate change impacts for this area providing information at localized heritage sites and on the Bay as a whole.

Keywords – Climate change; Archaeological survey; Maritime heritage; UAV Mapping; Palaeo-environment.

1. Introduction

1.1 Erosion of the cultural landscape

Ballinskelligs Bay (Fig. 1) on the south western extent of the Iveragh Peninsula in Kerry opens onto the Atlantic Ocean, this position along the western seaboard of Europe means the Bay is located along one of the most exposed coastlines to storms in Europe. Ballinskelligs Bay has been a formative part of many different human landscapes throughout time, today we encounter it as a settlement and recreational landscape, having previously played a pivotal role within Kerry's monastic landscape.

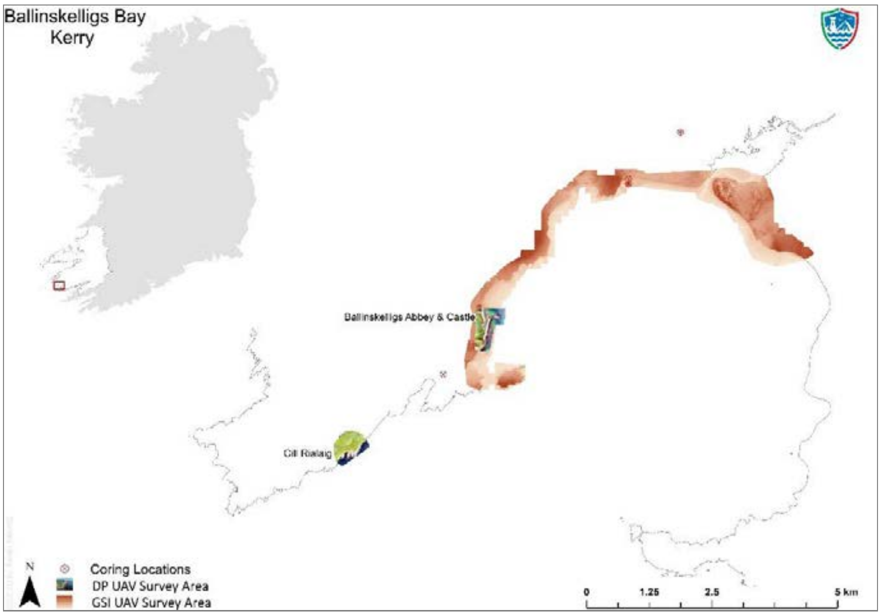

Figure 20: Locational Map of Ballinskelligs Bay showing survey areas of the CHERISH project

The UNESCO World Heritage Site Skellig Michael lies off the Ballinskellig coast. In the 11th century due to various stresses the monastery of Skellig Michael was transferred to the north shore at Ballinskelligs (Smith, 1756, 103; S.M., 1913, 165-6; Henry, 1956, 116). The priory of the Arroasian Canons of the Order of St Augustine was founded around 1210, or shortly afterwards, originating from Rattoo in north Kerry, it retained possession of Great Skellig and of the alias 'de Rupe Michaelis'. The priory was still Arroasian and occupied by canons in 1555, and may still have been in use by 1569 (O'Sullivan & Sheehan, 1996). By August 1578, the monastery is dissolved and letters patent detail the lease of the late monastery of Canons of Ballinskellig and its associated holdings including Skellig Michael to Gyles Clinsher, ownership continued in private hands into the late 19th century (Hickson, 1890, 312; Henry, 1956, 117). The priory comprises a number of buildings which exhibit architectural details relating to various periods between the 13th and 15th centuries.

Figure 21: Unmanned Aerial Vehicle image of Ballinskelligs Abbey

In the mid-18th century, the erosion at the of the Priory is recorded as extensive (Smith, 1754, 103). The Office of Public Works (OPW) has undertaken construction of a substantial sea-wall, revetted by groynes. The first phase of seawall construction was at the turn of the 20th century. The priory buildings have been the subject of restoration projects by the OPW, which include substantial repairs and building works alongside repointing and general maintenance. In October 1962, erosion uncovered human remains on the sea-shore in front of the Priory.

Figure 22: Unmanned Aerial Vehicle image of Balliskelligs Castle and Harbour

To the north of the Priory, McCarthy's castle sits on the tip of a narrow promontory of land that juts into the sea. This tower house is probably 16th century in date and associated with the McCarthy's who were chieftains in Cork and Kerry. The history of the tower house appears to be closely linked to that of the nearby priory during the later 16th and 17th centuries

(O'Sullivan & Sheehan, 1996). It may be identified as the manor that along with the Priory and associated lands were bestowed on the Sigerson family by Richard Harding in the early seventeenth century (Lynch, 1902, 352). This promontory suffers badly from erosion and has changed substantially in living memory. The tract of land that joined the 20th century concrete harbour (Fig. 3) to the Castle peninsula has been eroded resulting in the destruction of the harbour and its separation form the mainland. The harbour jutted out into the sea and its construction potentially accelerated this land erosion.

Figure 23: Left Image- Ballinskelligs Castle (Crawford, 1923); Right Image- Ballinskelligs Castle (CHERISH, 2018)

This three storey rectangular tower house rises from a battered base built on bedrock. Its walls are built of split stone laid in a strong, pebbly mortar with marine shell inclusions. The quoins, many of which are missing, are of dressed sandstone and are alternately face-bedded. At each floor level the plan of the building consists of a main chamber with an adjoining mural passageway. Access to the upper floors of the structure is gained by means of a mural stair, approached from the entrance lobby through a doorway which could be secured from within. The castle ruins remain largely intact; however, the southern corner is badly damaged with a breakthrough in the wall in this area. This is partly due to it being the location of an ope, exposure to the sea and the wall being thinner due to the mural stairs located in this corner of the tower house.

Following erosion of tracts of land around the castle, excavations were undertaken by John Sheehan, University College Cork during two seasons in 1988 and 1991. The excavations focused on the area under the garderobe chute-ope, the interior of the castle and to the south east side of the castle. On the south east side of the castle, winter storm in 1987-1988 caused the loss and exposure of archaeological layers. The excavations in this area revealed two external lean-to structures with pitched-cobble floors, both of which post-dated the primary period of occupation of the castle. It is believed to have been a fish curling station, most of the finds were post medieval in date. Sir William Petty is recorded as having established a fishery in the 17th century at Ballinskelligs. Two early twentieth-century photographs of the castle (Crawford, 1923) show that a building formerly stood against its north east wall. This appears to have been of relatively modern date, as it is not noted in OSL and does not feature in the Lawrence Collection photographs of the site. The castle interior excavation discovered the large paving slabs of the original ground floor beneath a considerable build-up of storm material.

Figure 24: UKHO 1855 map showing west shore of Ballinskelligs & CHERISH sites: Ballinskelligs Priory, Castle and ancient Hamlet site are all visibly depicted on this navigational chart (© UKHO: D18460)

An ancient hamlet is located approximately 120 metres to the north west of Ballinskelligs Priory, just beyond the northern extent of the OPW seawall. This area is being affected by erosion, that may be attributed to the hard defences in the area. A complex of grass-grown stony banks represents up to eleven possible structures, with exposed sections of coursed drystone walling. The majority of structures visible are rectangular in outline with three circular examples present. Scattered throughout the site are a number of sod-covered mounds. It is possible this settlement is associated with the pilchard fishery was established at Ballinskelligs by Sir William Petty (De Courcy, 1981).

On a south east facing slope at the entrance to Ballinskelligs Bay is the early medieval ecclesiastical site of Kilreelig with a view over the mouth of Kenmare Bay to the Beara Peninsula. This site comprises a cashel wall with oratory, circular hut, cross-slabs and leacht with a nearby holy well. This significant cultural heritage site played an important position in the monastic landscape of Ballinskelligs Bay.

Significant cliff erosion can be found all around Ballinskelligs Bay. Exposed peats and intertidal forests are visible on the storm beach between the Priory and Castle and along the western side of Inny Strand. In the spring of 1989, on the western side of Inny Strand during a period of high tides and stormy weather, a series of twenty-seven cultivation ridges were exposed. An intertidal wreck is located at the mouth of the Inny River.

2. Methodology

The baseline survey of Ballinskelligs Bay utilised various components of the CHERISH toolkit.

2.1 Laser Scan Survey

In June 2018, the Discovery Programme (DP) team collected terrestrial laser scan data of McCarthy Castle. The laser scan system employed for the acquisition of data was a Faro Focus 120 phase-based laser scanner with spherical targets. The data was georeferenced using a Trimble 5800 real-time kinematic differential GPS system, using the VRS Now correction service. The coordinate system utilised was Irish Transverse Mercator (ITM). The pre-defined survey profile used was 'Outdoor - up to 20m', with the RGB values recorded. This defined a point-spacing of 7.67mm at 10m, with each scan taking less than 10 minutes to complete.

Figure 25: 3D point cloud captured using Faro Focus 120 Laser Scanner

2.2 Unmanned Aerial Vehicle Survey

In June 2018, the DP undertook a concentrated Unmanned Aerial Vehicle (UAV) survey of the western shore of the bay encompassing the area from the Priory to the Castle. The Discovery Programme uses a DJI Phantom 4 Pro drone for the 3D mapping of local landscapes. Projects are planned and executed using the DJI Ground Station app hosted on an iPad mini. This allows flight lines, photo overlap, flying height and other parameters to be defined which determine the ground resolution of the resulting photography. Generally, a flying height of 80m is selected, resulting in a ground pixel size of approx. 2.5cm. Ground control markers are distributed around the perimeter of the survey area and mapped using a Trimble R10 GNSS receiver, operated using the Trimble VRSnow network correction service. Photogrammetric processing is undertaken in Agisoft PhotoScan Pro, to generate a Digital Surface Model (DSM) and orthoimage of the local landscape.

The Geological Survey of Ireland (GSI) gathered an 8 km stretch of coastal UAV survey focused on the north and west of the bay. The GSI use a light-weight, fixed-wing SenseFly eBee Plus UAV with a built-in Soda RGB F/2.8-11 with a 10.6mm Camera, flown at an average height of 100m. This produces an output with a ground sampling distance of 2.3cm. Geo-referencing of the data capture is through the high-precision built-in RTK/PPK functionality. Checkpoints were distributed around the perimeter of the survey area across different elevations and surface types, for example grass, sand and hard ground. The checkpoints were mapped using a Trimble R4 GNSS receiver. Photogrammetric processing is undertaken in Pix 4D, to generate a Digital Surface Model (DSM) and an orthoimage of the local landscape. This survey will be repeated in the final years of the project to measure rates of change that have occurred along this stretch of the coast.

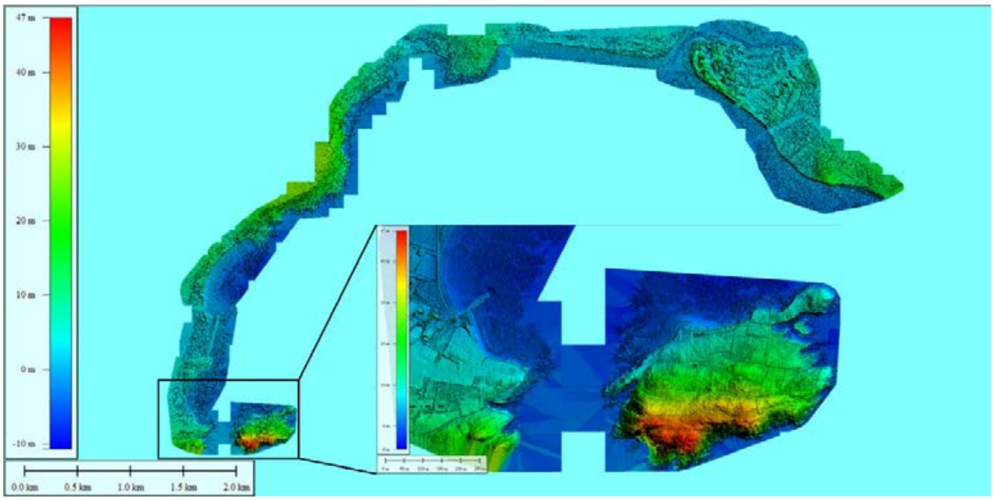

Figure 26: Results of the Unmanned Aerial Vehicle survey of the intertidal zone of Ballinskelligs Bay

2.3 Palaeo-environmental investigations

In May 2019, the team from the Geography Department, Aberystwyth University (AU) were joined by member of the DP for the collection of cores from four locations in Ballinskelligs bay. The team used two coring methods. The first method employed used a Russian Corer. This is a half cylinder with the chamber covered by a metal flap and is ideal for collecting sediments from bogs and mires where the surface can support the 2 or 3 people needed to operate it. Typically, 0.5 or 1 metre in length, the corer is pushed into the sediment and at the correct depth, it is rotated through 180° which opens the flap and fills the chamber with an undisturbed sample from that depth. A complete, overlapping sequence is taken alternately from 2 adjacent holes as the nose of the corer disturbs the sediments immediate below each sample. The sequence is simply collected by rotating the flap and transferring it to a plastic tube for detailed analysis back in the laboratory.

Percussion coring is used to penetrate sediments where traditional, hand operated corers are precluded due to the sediment type, density or compaction of the material to be sampled. It consists of a hollow, metre-long steel tube that is driven into the ground by a petrol-driven percussion hammer and extracted with a manual jacking system. The diameter of the core barrel employed is usually 55mm (other sizes and types are available), and it retrieves cores up to 1 metre in length. The core extraction system is a hand-operated jacking unit that incrementally raises the core barrel from the sediment.

The palaeo-environmental cores are gathered in order to provide data on sea level change, pollen records and dates of deposits. The four coring locations in the area of Ballinskelligs Bay are denoted in Fig. 1. The core taken to the south west of the Bay is located in the townland, Baile Ji Chuill and shows 5.5m of organic phragmities peat overlying pinky-grey silts and clays. Basal peats from this core have been dated to 6,323 - 6,481 cal. BP. The most northerly core location at Emlagh Mor is a 4.5m sequence of sphagnum peat overlying pinky-grey silty clay. The basal peat returned a date 5,674 – 5,902 cal. BP. These first two coring locations utilised a Russian corer. The third and fourth coring locations on Inny strand utilised a Percussion corer due to the compaction of the sediments in this area. The team obtained a low tide core, an inshore core and a tree stump sample for dating. The tree stump was identified as pine and produced a date of 3,985 – 4,148 cal BP. The low tide and inshore core have the potential to tell when the formation of peat was halted by the arrival of the beach.

Figure 27: Percussion coring at the low tide mark by Aberystwyth University, Inny Strand, Ballinskelligs Bay

2.4 Walkover Survey

The walk-over survey involved Discovery Programme Archaeologists and Surveyors covering large tracts of the Bay, with individuals spaced to ensure overlapping field of visions, approximately following transects 15m apart. Only finds at risk of being lost or moved out of context were to be recovered with locations logged. Sites of archaeological potential were identified, with a written record and positional data captured. Positional data is captured with a hand-held Garmin GPS with an accuracy of ± 3m. The areas chosen for walk-over survey are influenced by historic and cartographic research.

Figure 28: Walkover survey, Ballinskelligs Pier

The areas outlined for walkover survey were the monastic site at Kildreelig, and the intertidal area to the west and north of the bay that complemented the UAV survey of the Bay undertaken by the GSI (Figure 1). This area started at Ballinskellig's Priory and finished at Waterville golf course, located to the east of the mouth of the Inny. The team undertook additional focused site visits of areas within Ballinskelligs Bay identified due to cartographic and desk-based research.

3. Discussion and Conclusion

The cultural heritage of Ballinskelligs Bay includes a variety of archaeological site types and narratives in regard to local, national and internationally significant histories. The ongoing erosion at Ballinskelligs Bay is readily identifiable through its impacts on the built heritage located to the north west of the Bay, coastal erosion in this area has eaten extensively into the seaward extent of the Priory grounds and buildings. Storm events have continued to impact this site since the building of the seawall. The UAV surveys have created 3D point clouds and Digital Surface Models providing measured plans of the Priory building and how its sits within the wider environment of the Bay. At the northern terminus of the Priory seawall, accelerated rates of erosion due to the building of this hard defence are impacting the ancient Hamlet. The CHERISH team are investigating the potential to undertake geophysical survey on this site. McCarthy's Castle sits at the end of a peninsula surrounded by the sea on three sides. The site of the castle was the subject of excavations in the late 80's and early 90's due to the threat of coastal erosion and storm events. The targeted laser scan survey of the castle provided a point cloud 3D model, elevation, cross-sections and floor plans. Throughout Ballinskelligs Bay erosion and loss of land is evidenced by soft sediment cliff collapse.

The dated tree stump form Inny strand tells how a Bronze Age forest was present in the north of the bay, this forest potentially extended much further past the low water mark as illustrated by the buried peats we encounter today. The basal dates of the peat cores around the Bay inform of the formation dates and phases of the wetlands that now encompass Ballinskelligs Bay. These peat cores will provide further insights by producing environmental and climate records for the Bay since the Neolithic Period. Archaeological sites around the Bay such as a Wedge Tomb built before the formation of the bog recorded by Lynch (1902) and later excavated by Herrity in the 1960's provide further information on the date of the peat formation within the Bay.

The measured and observational CHERISH baseline dataset created records of the condition and character of coastal cultural heritage sites within Balliskelligs Bay contributing to and enhancing the National Monuments Service Sites and Monuments Record. The mapping of vulnerable locations, rates of change and quantity of loss informs on the geomorphology of the Bay. Over the millennia the changing geomorphology and hydrodynamic properties of the bay have impacted on each other and continually influenced marine zone dynamics. This type of measured data informs on site management issues providing insights into measured rates of change and creating records for management of loss. The baseline data can be used as a comparative survey to earlier site records, CHERISH monitoring or any future surveys. The pattern of change recorded around the bay since at least the mid-18th century alongside consideration of climate change impacts such as predicted global rise in sea level indicates that in time if human intervention is not consistent and planned taking into consideration the hydrodynamic processes of the bay coastal heritage will continue to be impacted. The longevity and impacts of any planned interventions will inevitably vary across the bay as is visible today.

Ballinskellig's is a demonstration site of the Interrag Northern Periphery and Arctic 2014-2020 Programme funded project Adapt Northern Heritage. CHERISH have worked closely with Adapt Northern Heritage on this site and have attended stakeholder workshops and outreach events hosted by Adapt Northern Heritage in Ballinskelligs.

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Greenland's Wild West: Cruise Ships, climate change and threats to heritage sites

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Abstract

Climatic effects, such as melting sea ice and longer summers, have created new opportunities for access in the Arctic that has led to a tourism boom in recent years. This paper explores the current knowledge gap on the effects of a rapidly shifting climate and an increase of visitors created through cruise ship tourism. At present, there is a race to keep Heritage management and monitoring strategies at pace with increasingly visible climate and human impacts—however, the reality is that many cruise ships operate in Greenlandic waters and visit heritage sites with very little oversight or formal guidelines for directing visitor behaviors. Using case studies from the two newly inscribed UNESCO World Heritage areas of Kujataa and Aasivissuit-Nipisat, we discuss current efforts underway to examine the coupling effects of climate change and human impacts in Greenland. Understanding the relationship between climate change and tourist behaviours provides a useful starting point for identifying the enormous challenges ahead as the country becomes a target destination for international visitors.

Keywords – Arctic, cruise ships, tourism, heritage, climate change

1. Introduction

A warming climate and sea ice reduction has led to increased access to the circumpolar North and the emergence of new land- and sea-based tourism opportunities in the Arctic[i] [ii].Cruise ships and smaller expedition ship tours have become increasingly popular, with Greenland becoming a primary destination for cruise companies operating in the Baffin Bay and Davis Straight region[iii]. Recent statistics show a dramatic leap in the number of cruise ship passengers travelling to Greenland from 2014 to 2018, with an astounding 126% increase over the five-year period[iv]. This trend has enormous implications for the country's UNESCO World Heritage properties of Ilulisaat, Kuujata and Aasivissuit-Nipisat, as Arctic cruise companies now market tour packages with landings at the major cultural heritage and archaeological sites found inside the World Heritage areas. These landings can comprise anywhere from tens to hundreds of individual persons, with only a few guides to oversee or direct the flow of visitor traffic and behaviour while on-site. Guides are usually short-term contracted workers and levels of expertise vary in both knowledge of the local cultural heritage, wildlife and experience with crowd control. Additionally, many of the heritage sites lack the infrastructure to handle the influx of huge groups—for example, clear signage, walking paths, waste removal, restroom facilities, etc.

The increasing pressures from large groups of tourists on heritage sites combined with a warming Arctic presents a significant challenge to the Greenland National Museum, UNESCO Site Managers and local stakeholders in Greenland. At the same time, there is an urgent political desire for Greenland to develop a robust and competitive tourist industry which is seen as a major strategic component of achieving a sustainable future for the country in the coming decades[v]. The situation presents a catch-22; on the one hand, the warming climate has created large ice-free zones, safer sea routes and longer summers seasons for cruise ships and pleasure crafts visiting Greenland. Simultaneously, climate change is driving an on-going process of preservation loss and degradation to heritage through melting permafrost, erosion and vegetation overgrowth, making some heritage sites especially vulnerable to human disturbances[vi vii viii ix].

Not surprisingly, "climate change" has been framed as a major selling point for tourism in Greenland: many visitors that travel to the Arctic are drawn by the desire to see and experience glaciers, wildlife and traditional ways of life before they are "lost forever". This existential climate change narrative has garnered significant attention in the media and is feeding into the growth of a special type of *last chance tourism* in Greenland that is already seen in other parts of the Eastern Arctic[x].

The newly inscribed UNESCO World Heritage sites of Aasivissuit-Nipisat and Kujataa offer interesting case studies for 'unpacking' the coupling effects of climate change and mass tourism on heritage resources in the Arctic. Although the two properties are vastly different in terms of their local environmental conditions, microclimates, histories, local economies and heritage assets—both areas represent vulnerable cultural landscapes representative of Greenland's past *and* future with the opportunity for cruise ships companies and local tour operators to offer new destinations and develop new types of tourist products. However, the current lack of preventative legal safeguards, infrastructure, facilities, and a comprehensive national tourism strategy has turned Greenland into a 'Wild West' for the cruise ship industry: access to sensitive heritage sites remains generally unregulated and there is no obligation for cruise ship companies or tour operators to self-report where and how many visitors are landing on a site. Because of this there is a desperate need for knowledge regarding how to facilitate sustainable tourism in these localities with respect to preserving cultural resources and controlling visitor flows[xi]. In order to deal with this emerging situation, new methods to detect, monitor and quantify site changes must be developed in Greenland.

2. Cruise Ship Tourism and Greenland's "Wild West"

At the moment, the legal framework for the protection of cultural heritage is defined under two of Greenland's Self-Government Parliament Acts: (1) Inatsisartut Law No. 11 of 19 May 2010 on the protection and other cultural heritage protection of cultural monuments (hereafter, *Heritage Act*), and (2) Inatsisartut Law No. 8 of 3 June 2015 on museum services (hereafter, *Museum Act*). The Heritage and Museum Acts define the specific protection measures for cultural monuments, heritage sites and all their components, and defines Nunatta Katersugaasivia Allagaateqarfialu (Greenland National Museum and Archives) as the supervisory body responsible for protection and conservation of the country's cultural assets. Within the Heritage Act, §5 and §6 define the conditions for what constitutes an ancient monument of cultural or historic value (i.e. cultural feature that pre-dates AD 1900), with special provisions laid out describing that these monuments cannot be altered or disturbed and that with few exceptions, no destructive activities may take place within a distance of 2 meters of the ancient feature.

In combination with the Heritage and Museum Acts, supplementary protective legislation was further enacted by Naalakkersuisut (Greenland Self-Government) to safeguard the three UNESCO World Heritage Areas of Ilulissat, Kujataa and Aasivissuit-Nipisat (Table 1) in Greenland. These protective measures provide more specific language on the protection of cultural monuments/areas within the defined boundaries of the UNESCO properties as well as specific clauses that prohibiting activities that may degrade the aesthetic character, traditional lifeways or Outstanding Universal Value (OUV) of the areas. These orders constitute a secondary level of protection of the properties and provides the National Museum, municipal governments and relevant stakeholders with a tool to adapt to changing circumstances and enforce greater restrictive measures of access to certain areas within the UNESCO properties if they are deemed of being negatively impacted by development.

Table 7. UNESCO World Heritage areas in Greenland and special protective legislation.

UNESCO property	Naalakkersuisut (Self-Government) order
Illulissat	Home Rule Executive Order No. 10 of 15 June 2007 on the protection of Ilulissat Icefjord.
Kujataa	Self-Government Order no. 16 of 5 July 2016 on other cultural heritage protection of a cultural-historical area in southern Greenland, consisting of bounded areas around sites Qassiarsuk, Igaliku, Sissarluttoq, Tasikuluulik og Qaqortukulooq-Upernaviarsuk.
Aasivissuit-Nipisat	Self-Government Order No. 1 of 30 January 2018 on other cultural heritage protection of a more defined area in West Greenland around Aasivissuit-Nipisat.

While identifying the authority of the agencies responsible for the management of the properties, it is important to understand that the Naalakkersuisut orders refrain from providing specific language on the implementation of management decisions of the properties or their assets. Oversight and protection of the areas remains at the discretion of the Site Managers and the Steering and Management groups overseeing each property.

At present, one of the main obstacles to the management of visitors in the UNESCO areas is the lack of data, self-reporting and direct communication between Greenlandic agencies and the cruise ship companies. In recent years, however, the Arctic Expedition Cruise Operators (AECO)[xii] network has been a valuable ally in Greenland and has worked diligently to share information and promote sustainable tourism in throughout the Arctic. However, AECO only works directly with expedition-type cruise vessels and not larger conventional cruise vessels. A brief review of all commercial ships with ports of call in Greenland in 2019 shows only ~49% of the total number of ships and their parent companies are currently members of the AECO network.

At present there is no legal obligation on the part of any private or commercial vessel to report site visits or share information on the numbers of passengers landing on a site in the UNESCO properties. AECO has made available the PAX (passenger + crew) numbers for expedition cruise vessels that have made ports of call at several of the Key UNESCO sites between 2017 -2019 (Table 2). Although these numbers reflect the aggregate totals of passengers and crew aboard a vessel during a port-of-call in one calendar year and not the number of passengers landing from ship-to-shore on a visit—they still provide insight into which Key sites are becoming more popular destinations for the expedition cruises. Anecdotal reporting from local tour operators and stake-holders in the UNESCO areas suggests that the number of both conventional and expedition cruise ship visits in the UNESCO areas has been steadily increasing.

Table 8. Unpublished AECO PAX (passenger + crew) data. Numbers reflect only aggregate numbers of individuals aboard vessels with ports of call at the Key Sites in the UNESCO properties, 1 January 2019 -19 November 2019[xiii]

UNESCO property	Key Site	2017	2018	2019
Ilulissat	Sermermiut	6452	9336	9709
Kujataa	Qassiarsuk (Brattahlíð)	720	1093	1520
	Tasikuluulik (Vatnahverfi)	-	-	-
	Qaqortukulooq (Hvalsey)	1044	1432	2700
	Sissarluttoq			
	Igaliku	141	653	902
Aasivissuit-Nipisat	Aasivissuit	-	-	-
	Itinnerup tupersuai	-	-	-
	Saqqarliit	325	161	-
	Sarfannguit	228	-	-
	Arajutsisut	-	-	-
	Innap nuua	-	-	-
	Nipisat	-	756	-

3. Challenges and Opportunities

To address these knowledge gaps, research is being conducted by the Activating Arctic Heritage (AAH) project through collaboration with local stakeholders in two of the Greenland UNESCO properties: Kujataa and Aasivissuit-Nipisat. AAH is a four-year research collaboration between the Greenland National Museum and Archives and National Museum of Denmark (sponsored by the Carlsberg Foundation) and comprises several different work-packages that include interdisciplinary archaeological and environmental investigations, historic climate studies and community knowledge sharing. The project explores this historic moment of transition in Greenland, where focus on the country's cultural heritage is quickly shifting from local to global scale. Environmental investigations by the AAH project build on the success of field methods and protocols developed by the REMAINS of Greenland project (2016-2019)[xiv]. To illustrate some of the ongoing work at the Key UNESCO sites, two specific sites are discussed to showcase the research examining the interplay between environmental change and human (i.e. tourist) impacts.

3.1 Nipisat Island

The small island of Nipisat possesses a spectacular diversity of well-preserved archaeological features[xv] and was chosen as a Key Site in the UNESCO property due its representative character of several phases of ancient and historic activity by past peoples in Greenland. On the eastern end of the island, a ca. 4,000-year old Saqqaq camp was excavated in the 1990s[xvi]. To the west of the Saqqaq site is a burial ground containing four Christian graves and a little further still the ruins of a large Colonial era warehouse. A little further to the north is an ancient Thule Inuit burial ground containing over 17+ grave features. To the east of the burial ground, on a gravel terrace, are traces of a playground for Inuit children, replete with miniature stone-built boats and a Inuit style tent house.

A small cove on the southern central shore of the island houses a ruin complex representing both colonial and Inuit dwellings. The cove was the site of the second colony project by the Danish authorities in Greenland in 1724. The main house was burned down by Dutch whalers ca. 1725 and rebuilt by the Danes in 1730. Remains of several Thule Inuit stone- and turf houses are found in the footprint of the old Colonial house ruins. These turf houses re-used the original walls of the colonial quarters. Following the shore towards the west, on a small escarpment in the middle of the cove is a cannon battery platform, used to defend the settlement. On the western side of the cove are the remains of at least three communal Thule Inuit houses, most likely built after abandonment of the colony. Finally, as one traverses across the rest of the island, numerous individual graves, fox traps and hunting features dot the landscape, representing an intense use of this island and its importance within the larger cultural land- and sea-scape of the Aasivissuit-Nipisat property.

The island's prominence as a Key Site has made it a target destination for both local tour operators (providing day-trips from the nearby port city of Sisimiut), as well as the smaller class expedition cruise ships that can navigate the narrow straight between Nipisat and the small rocky outcrop of Priest Island. Landing on Nipisat is moderately with smaller boats and zodiacs and in 2019 a temporary path was established across the island along with recommendations for operators on where and where not to take visitors to minimize trampling and disturbance of the island's vegetation and sensitive archaeological ruins.

As part of the long-term management strategy of the island as a Key Site, the Site Manager, UNESCO park ranger and the Sisimiut Museum have begun working with researchers from the AAH project to investigate and establish several baselines for monitoring change on the island. AAH researchers have installed environmental and atmospheric monitoring equipment (e.g. air temperature, precipitation rates, soil temperatures and soil moisture content), performed high-resolution drone and differential GPS mapping and will continue to collect environmental data over the next few years. Already, sub-surface investigations performed over the summer of 2020 have shown that preservation conditions on Nipisat are still quite outstanding with well-constrained permafrost layers and only some minor coastal erosion affecting the integrity of archaeological features on the south shore. The most immediate risks to the heritage on the island appear to be through human and animal activity. Fox holes are observed as increasing in frequency at the colonial warehouse and evidence of past human disturbances (e.g. manipulation of stones and looting) are observed in many of the graves.

To document and interpret these types of human impacts, a new Vulnerability Assessment protocol has been designed and implemented by cultural heritage managers from the Greenland National Museum and Sisimiut Museum. Data collected will eventually supplement the creation of an AECO Site-Specific Guideline (SSG). This Vulnerability Assessment follows a systematic scoring approach developed by the Norwegian Institute for Nature Research (NINA) used in the monitoring of Norwegian National Parks and several important historic heritage sites in Svalbard[xvii] [xviii]. The assessment applies numeric values to several different individual features observed on a site with aggregate scores combined to produce an overall vulnerability ranking for the whole heritage site.

The current goal is to complete and publish an SSG for Nipisat by the summer of 2021. Visitors to Nipisat, as well as tour operators and cruise ships, will be obliged to follow the guidelines. The information will provide clear directions on access and navigating the site's main attractions and advice for promoting sustainable use of the area when landing by boat on-site (i.e. do's and don'ts).

Lastly, a beta-version mobile app for tour operators is in development by the Greenland National Museum that will be provided as a voluntary means of recording day-to-day site visitor volume on Nipisat (and the other Key Sites). This information will provide some basis for informing the Aasivissuit-Nipisat Site Manager on the timing and amount of visitor landings in the coming years. This data will also feed into the AAH research and help contextualize the environmental data in relationship to observed human impacts. The information collected is also of value to local tour operators who visit the site with frequency and provides a secure line of communication for them to report disturbances directly to the Site Manager, Park Ranger and Greenland National Museum.

3.2 Qassiarsuk (Brattahlíð, Ø29/ø29a)

Qassiarsuk is one of five component areas that comprise the Kujataa UNESCO World Heritage property[xix]. Qassiarsuk spans an area of 113 km^2 and is situated across the fjord from the international airport at Nassassuaq. This locality, along with several other sites located in the surrounding area comprise the core of the Norse Greenlandic *Eystribyggð* (Eastern Settlement), with Qassiarsuk believed to be the original location of Erik the Red's farm (Brattahlíð, Ø29/Ø29a), the first permanent Norse settlement in Greenland. It is also the area of South Greenland most intensively farmed in modern times with five single family sheep farms in operation today. The modern settlement has water and electricity, a primary school, football field, community hall, grocery, church, cemetery and a garbage depot. Because of Qassiarsuk's unique history and easy access it is visited by large numbers of international tourists every year. There is a hostel, a service house with showers and a launderette, and a few cabins/farmhouses for rent to the public.

In addition to the many Norse farm features and the church remains still visible at Qassiarsuk, there are also significant numbers of Thule Inuit and historic Inuit sites in the surrounding area—including the only confirmed archaeological evidence of Paleo-Inuit activity within the nominated property. There are at least four locations with Inuit winter houses, one dated to the 19th century and the others also likely to be recent or at least to have been used recently. In South Greenland, Inuit archaeology has frequently taken a backseat to Norse archaeological investigations in the past and therefore the number of Inuit sites in the area is probably significantly greater than what is currently known[xx]. In this area of South Greenland, climate change has already made itself visible with higher summer temperatures and even drought-like conditions in some years. Archaeological preservation is relatively poor when compared to the rest of the West coast and both natural and human-induced erosion are visible in several places within the UNESCO component areas.

Qassiarsuk has been a central destination for tourists visiting South Greenland for many years due to its reputation as being the original site of Erik the Red's farm (Brattahlíð, Ø29/Ø29a). The small settlement even possesses two modern Norse architectural reconstructions: a farmhouse and small chapel, both a short walk from the main Norse archaeological ruin group. With the arrival of large cruise ships in the fjord in the summer months, it is not uncommon to witness sometimes hundreds of visitor's deluge Ø29/Ø29a in a single afternoon. It is worth noting that while Qassiarsuk does have a gravel road to direct the flow of visitors to the main group of Norse ruins, there are no established pathways to direct visitors when they arrive on-site, and it is not uncommon to see guests sitting on stone and turf walls or wandering inside the house ruins to take selfies.

New work is planned for Qassiarsuk in 2020 that follows the approach implemented in Nipisat in 2019—but with adjustments to recognize that this is a quite different type of Key Site being investigated. For instance, in contrast to Nipisat which is remote and only accessible by a chartered boat or expedition cruise ship, Qassiarsuk is a living, active farm community with approximately 80 to 90 year-round inhabitants. Several of the distinctive Norse archaeological features found in Qassiarsuk are situated right next to private homes and farm buildings, and it is not uncommon to find a Norse house feature re-purposed into a private garden.

New informational signage will be installed in 2020 to hopefully improve this situation, as well inform visitors on proper behaviour and the requirements to not disturb the site's archaeological ruins. Preliminary work will also begin for implementing the above-mentioned Vulnerability Assessment protocol for Qassiarsuk in 2020. It will be interesting to see how a site of this type ranks in comparison to other sites due to the several pressures be placed on the site from not only climate effects and tourism, but also agricultural and pastoral activities.

4. Conclusion

The expected growth of passenger cruise ship tourism in Greenland presents both challenges and opportunities for developing robust and innovative new methods for identifying the intersection between climate driven environmental change and human impacts on cultural heritage. It is not reasonable to assume that as time goes on, heritage managers in Greenland will not find a 'one size fits all' solution for site management. Because each site is different, management approaches should remain flexible and adapt to changing circumstances year after year. The information derived the current AAH work provides one approach for developing a systemized and data-driven approach for identifying vulnerabilities and risks, while at the same time providing new knowledge for managing the influx of large-scale landings by cruise ships and passengers wishing to experience Greenland's unique cultural landscapes, history and heritage in the coming decades.

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Impact of Climate Change on Coastal Heritage Sites in County Kerry, Ireland

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Abstract
This paper deals with the effects of climate change on coastal heritage sites located on the south west coast of Ireland. The three case studies discussed below are National Monument sites in State care. The Office of Public Works (OPW) is responsible for their day-to-day maintenance and conservation. The sites used as case studies are Dunbeg Promontory Fort, Ballinskelligs Priory and Skellig Michael. Climate change has been affecting these sites and causing damage to their historic fabric. The OPW has taken mitigating measures to reduce the impact of climate change on these sites and protect their architectural, archaeological and natural features.

Keywords – Climate change; coastal heritage; coastal erosion; National Monument

1. Dunbeg Promontory Fort (An Dún Beag)

1.1 History and Background

The Dunbeg promontory fort is located on a sheer cliff overlooking the Dingle Bay in County Kerry, Ireland. It is a National Monument site in state guardianship and is one of the Wild Atlantic Way coastal touring sites. A local family privately owns the access path to the site. The fort contains four outer defensive banks of stone and earth. Inside the fort are the remains of a drystone Clochán (beehive hut) and a souterrain [1]. There is difficulty in determining a precise date to the site due to absence of dateable finds and records. A radiocarbon date of the inner fosse suggests that it dated back to the 8th or 9th centuries AD. Another radiocarbon date of the layers in the Clochán suggests that it was inhabited in the 10th or 11th centuries AD.

The fort suffered extensive erosion in the early 19th century, and in the 1977 OPW carried out an archaeological excavation to record the site and its history before any further damage could occur [2]. The excavations were carried out by archaeologist Terry Barry who excavated almost the entire interior of the monument. Further locations have been excavated in 2018 by archaeologist Laurence Dunne.

1.2 Climate Impact

Dunbeg fort is an iconic example of Irish coastal promontory forts and is one of many well visited sites on the Dingle peninsula. However, the location of the fort is making it vulnerable to natural weather events and is threatening the site's existence.

A considerable part of the cliff collapsed in recent years due to the increased frequency and severity of storms and precipitation. This has led to significant loss of the historic fabric and archaeological elements. The site is particularly vulnerable during the winter season between December and February due to its exposed location. A storm in January 2014 caused a portion of the cliff to collapse into the sea. Between 2017 and 2018, severe weather caused further damage and a significant part of the historic fabric including the entranceway was lost into the sea. The dramatic collapse has sparked national attention and was covered in the national news [3].

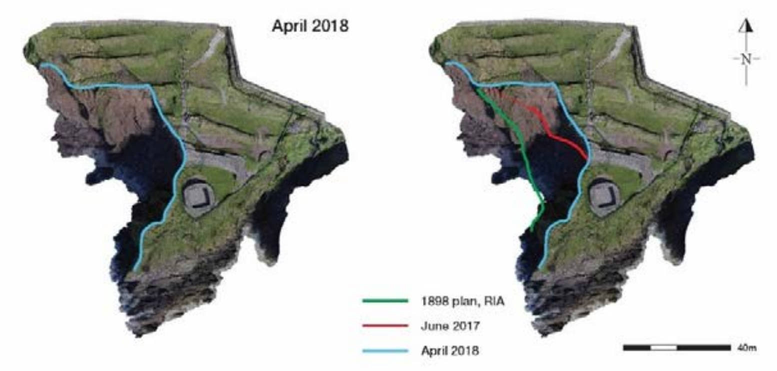

Figure 1- Coastal Erosion during recent years (The Discovery Programme)

1.3 Methodology and Guiding Principles

OPW have adopted a policy of managed retreat for the site. The main concept was to adapt to the present climate effects and to provide safe access for visitors. After the dramatic 2017 cliff collapse, the OPW applied for a Ministerial Consent from the Department of Culture, Heritage and the Gaeltacht (DCHG) to erect a boundary fence that kept visitors and tourists away from the dangerous site. Access could not be allowed until a safety risk assessment was carried out and a report was issued. OPW commissioned consultant engineers to carry out a geo-physical survey of the site. The site will now be continuously monitored to ensure visitors safety. The Discovery Programme has also surveyed the site using Unmanned Aerial Vehicle (UAV) mapping. It is worth noting that in the case of sudden and dramatic collapse, the site will be closed immediately, and access will be restricted to OPW personnel only.

The OPW applied for a second Ministerial Consent in 2018/2019 to install fencing to limit visitor access to specific areas that are considered safe. The existing drainage system has also been repaired and a new drainage wall has been constructed to redirect floodwater from the site. The site was reopened in 2019 to allow the visitors to visit the site and benefit the local tourist economy. The OPW and DCHG will install interpretation signage on site that will include a brief history of the site and educational information on climate change. The aim is to raise awareness of the visitors about the impact and challenges caused by climate change on the site.

1.4 Outcome

Further coastal erosion to the site caused by climate change is progressive and inevitable. The repair works on site have required substantial labour and financial resources. A large range of specialists have been involved with the proposed works including the DCHG archaeologists, OPW architects, consultant engineers, consultant archaeologists, OPW direct labour force etc. Local landowners and politicians have also been consulted. The site has been accurately surveyed to assess the damage and ongoing erosion. By keeping the site accessible to visitors, the OPW hopes to raise awareness of the public and visitors to the effects of climate change on coastal heritage sites. Similarly, the site can now be used as a case study for other vulnerable coastal heritage sites regarding adaptation to the effects of climate change.

2. Ballinskelligs Priory (Prioreacht Bhaile An Sceilg)

2.1 History and Background

Ballinskelligs Priory is located on the west shore of Ballinskelligs bay in county Kerry [4]. It was founded by the monks who came to the mainland from Skellig Michael between the 12th and 13th centuries. The remaining structures on site date back to the 15th century. They include two churches that have windows and doors with dressed stones, and a cloister garth with a large hall [1]. Ballinskelligs Priory is one of the significant spiritual sites dedicated to St Michael in the area. It is a destination for visitors searching for spirituality and history [5]. Its location on the Wild Atlantic Way also makes it a main tourist destination. The site contains a large graveyard that is still used by the local community.

2.2 Climate Impact

A significant amount of this historic site has been lost to coastal erosion. A concrete sea wall was built in the 1950s to prevent further loss of the site. The sea wall is now deteriorating and is in urgent need of upgrading and repair. The OPW has been carrying out conservation and repair works to the priory for the past 10 years. It is expected that the works will be completed in the next two years. In recent years, the increasing storm surge and water penetration to the site and over the sea wall, has caused damage to the ruined structures and threatened their survival.

2.3 Methodology and Guiding Principles

The OPW commissioned a structural inspection and report for proposed repairs to the sea wall in September 2019. The OPW has also commissioned conservation consultants to carry out a climate change risk assessment on the site, the first one of its kind on a national monument site in Ireland. It is intended to identify the potential risks to the site and develop a Climate Change Adaptation Guide.

The OPW is gathering a team of various consulting experts to advice on the most practicable solution for protection of the site from flood damage and erosion. The expert bodies consulted consist of OPW architects, Kerry County Council, OPW Flood Risk Management section engineers, consultant structural engineers, DCHG and consultant archaeologists. The repair works to the sea wall will be technically challenging and expensive and have to be carefully discussed with all stakeholders. Any proposed methods for the enhancement and repair of the sea wall cannot compromise or damage the ecosystem of the bay. A foreshore license from Kerry County Council to carry out the works will be required. A Ministerial Consent for carrying out works to the National Monument will also be required from DCHG [6].

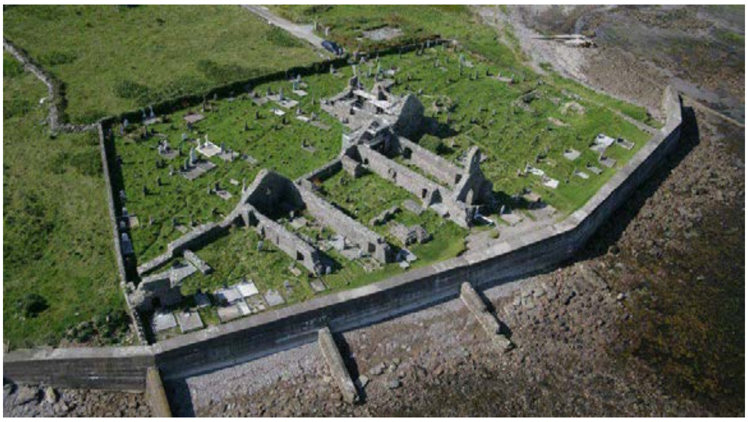

Figure 2- Aerial view of Ballinskelligs Priory and the existing concrete sea wall (DCHG)

2.4 Outcome

The repairs to the sea wall at Ballinskelligs Priory is a challenging task. The works will have to be carried out in a sustainable manner and the project has to be accurately costed. The health and safety of the workers on site will be prioritised especially during high tide and the completed works will have to be protected from any potential damage. Once repairs to the sea wall are completed, Ballinskelligs Priory will become a case study for other vulnerable heritage sites in the area.

3. Skellig Michael (Sceilg Mhichíl)

3.1 History and Background

Skellig Michael is an island located 13km off the South Kerry Coast and is home to an early medieval monastic site. It was founded by saint Fionán in c.6th century. The medieval monastery is dramatically situated on the top of the rocky island in the Atlantic Ocean. Due to climate change and increasingly rough sea, the monks later transferred to the mainland at Ballinskelligs Priory [1]. The monastery came into state care in 1880 and the OPW took on responsibility for managing and maintaining the monastic site. The island also contains two lighthouses built by the Commissioners of Irish Lights in 1821. They represent good examples of typical 19th century lighthouse architecture and are the subject of proposed long-term repair and restoration works by the OPW. Skellig Michael was inscribed on the World Heritage List in

1996 for its unique cultural and natural attributes. The uniqueness of the dry stone monastic structures displays the architectural achievement of the monks in such a remote and severe environment. The island is also important for being a destination for breeding seabirds and have a unique eco-system [7]. Skellig Michael is a designated Special Area of Conservation (SAC) under the Habitats Directive (92/43/EEC) and a designated Special Protected Area (SPA) under the Birds Directive (79/409/EEC). Both directives form part of Natura 2000, a European network of protected sites [8].

Figure 3- Aerial view of the monastery at Skellig Michael (DCHG)

3.2 Climate Impact and The Adopted Methodologies

One section of the monastery retaining wall at Skellig Michael has become structurally unstable due to the increase in rainfall and rainwater draining through it. The OPW has commissioned the Discovery Programme to monitor the movement of the wall. The monastery wall is now being surveyed on a yearly basis. The OPW is proposing the careful dismantling and rebuilding of the wall to address the rainwater drainage issue. The monastery wall will have to be carefully reconstructed without compromising the site's authenticity and Outstanding Universal Value (OUV).

In recent years, increased rainfall has resulted in increased rock fall that is damaging the fabric of the site and threatening the safety of both OPW staff and visitors to the island. For instance, in 2017 a rock fall occurred near the guides accommodation, causing a major safety risk for staff. The increased rock fall at times caused damage to the lighthouse road, an important architectural feature. The erosion is also the result of natural causes such as wildlife burrowing on site. Presently, the OPW carries out maintenance works four weeks prior to the opening of the island for visitors during summer. The island is open to visitors from May to October during the summer season. If the damage caused by rock falls increases, then the maintenance period will have to be extended accordingly.

3.3 Outcome

Rock fall is a high-risk threat to the safety of OPW staff and visitors. Both rock fall and increased rainwater are damaging the unique historic fabric of the site. OPW has carried out two rescue exercises last year that involved bringing a dummy casualty from the monastery to the pier on a stretcher. The Irish Coastguard Mountain Rescue team were involved in the rescue exercise and it is envisaged that a rescue exercise will take place during June of every year.

The increase in sea levels, sea swells and the increasing severity of storms have been affecting access to the landing pier. The number of days when tourists can access the island during the summer tourist season has been steadily decreasing. The viability of the island as a tourist destination will be affected by climate change. The long-term solution may involve raising the level of the existing landing pier to allow access to the island to compensate for rising sea level.

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Assessing Climate Change Risk at the Heart of Neolithic Orkney: Applying a Climate Vulnerability Index for World Heritage

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Abstract

Climate change is recognised as the fastest growing threat to World Heritage properties with many already experiencing significant negative impacts, damage and degradation. Located in the archipelago of Orkney off the north east of Scotland, the Heart of Neolithic Orkney (HONO) World Heritage (WH) property is at significant risk. In April 2019 HONO was the first cultural WH property chosen to pilot the Climate Vulnerability Index (CVI) methodology.

The CVI methodology was developed in recognition of a need for a tool capable of comparing climate change risks to different WH properties across the world. The process, as applied at HONO, assessed the climate vulnerability of the Outstanding Universal Value (OUV) for which the property is inscribed on the World Heritage list. It also assessed the resulting community vulnerability to these potential impacts. The results determined HONO's Combined OUV Vulnerability as High, while Community Vulnerability was Moderate. Compounding socio-economic-cultural factors were identified. Key themes and questions that emerged included noting a policy gap re: the inability to update out-of-date sections of Statements of OUV, research gaps around climate drivers and impacts, and the need to make difficult management choices in future with input from stakeholders and community.

The HONO CVI was planned and delivered in partnership between Union of Concerned Scientists, James Cook University (Australia), Historic Environment Scotland (HES), University of the Highlands and Islands Archaeology Institute and Orkney Islands Council, and with support from the ICOMOS Climate Change and Heritage Working Group.

Keywords – World Heritage; Scotland; Climate Vulnerability Index; Climate Change; Community

1. Introduction

Climate change is now recognised as the fastest-growing threat to World Heritage properties with many already experiencing significant negative impacts, damage and degradation (ICOMOS 2019). The Climate Vulnerability Index (CVI) is a recently-developed methodology to assess climate change impacts on all types of World Heritage properties (Day *et al.* 2020). In April 2019 HONO became the first cultural WH property chosen to pilot the CVI methodology to assess the climate vulnerability of the Outstanding Universal Value (OUV) for which the property is inscribed on the World Heritage list. It also assessed community vulnerability to these impacts on OUV via economic, social and cultural dependencies in the context of the community's adaptive capacity. This paper briefly summarises the HONO CVI process and its results, highlights some key themes, and seeks to connect them to the challenges of managing the HONO WH property. It also touches upon wider issues of managing World Heritage across Scotland, UK and more broadly.

2. The Heart of Neolithic Orkney World Heritage Site

Orkney is an archipelago of about 70 islands lying 15 km of the north-eastern extremity of mainland Scotland where the North Atlantic meets the North Sea. The HONO WH property is located in the west of Mainland, the largest island of the archipelago. The property comprises four Neolithic sites (Figure 1.):

- Skara Brae settlement
- Maeshowe chambered tomb and the associated Barnhouse Stone
- The Stones of Stenness and the associated Watch Stone
- The Ring of Brodgar and associated monuments

The WH property boundary is tightly drawn but is surrounded by a much larger two-part Buffer Zone (Figure 1). Skara Brae is located on the coast, facing into the North Atlantic, while the other three sites are located close together in central west Mainland in a geographical bowl containing two interconnected lochs.

The site was inscribed on the World Heritage list in 1999 for the combination of ceremonial, funerary and domestic sites that together bear a unique testimony to a cultural tradition which flourished between *c.* 3000 and 2000 BC. They represent different facets of a dynamic and accomplished society: from domestic life at an extremely well-preserved settlement site, through ceremonial expression at two monumental stone circle and henge sites, to beliefs and practices associated with death at a great chambered tomb. Individually, the sites are masterpieces of Neolithic construction, and together they comprise one of the richest surviving Neolithic landscapes in western Europe.

The UNESCO *Operational Guidelines for the Implementation of the World Heritage Convention* (UNESCO 2019) state that WH properties should have a function in the life of the community, and that access for visitors should be provided wherever possible, so long as these do not impact adversely on the protection and management required to preserve the OUV. Balancing these needs has implications for management prioritisation and decision making, including proposals designed to address climate impacts. In addition, HONO, as with all WH properties, has a range of other non-OUV values of national, regional and local significance which should also be managed for.

Figure 4. Location of Heart of Neolithic Orkney World Heritage Site, the individual monuments that comprise the property, and the two-part Buffer Zone.

3. Background to CVI

"Climate change has become one of the most significant and fastest growing threats to people and their heritage worldwide". (ICOMOS 2017)

"Climate change is the fastest growing threat [to World Heritage] the most significant potential threat and, for a number of sites, this threat is materialising, with tangible impacts on World Heritage values". (IUCN 2017)

There are currently 1121 World Heritage properties in 167 nations worldwide, representing extraordinary diversity: from cathedrals to coral reefs to city centres to cultural landscapes. At present the UNESCO List of World Heritage In Danger is the primary tool for dealing with at-risk sites, but this was developed to deal with localised threats that could be resolved at a national level with sufficient will and resources. Clearly placing a large and increasing number of climate-threatened WH properties on the In-Danger list is neither desirable or effective. This revealed a lack of tools that the World Heritage Centre and Advisory Bodies could use to compare "apples to apples" when assessing climate threats to WH properties. The CVI methodology was developed in response to this gap, to offer a transparent and repeatable tool that could be (relatively) rapidly applied to different sites (Day *et al.* 2020).

CVI was first trialled at a natural WH property, Shark Bay, Australia in 2018 (NESP Earth Systems and Climate Change Hub 2018). Piloting the CVI collaborative workshop process at a cultural WH property was an important next step in testing and developing the methodology. HONO was chosen for several reasons, including: existing recognition of the Site's vulnerability to climate change; HES leadership and innovation in addressing climate change and heritage; support from the ICOMOS Climate Change and Heritage Working Group; involvement of the Archaeology Institute at the University of the Highlands and Islands; the local availability of a diverse array of researchers, other experts and engaged stakeholders; and the availability of relevant climate change data and research and recently updated regional climate scenarios (Day, J. *et al.* 2019, Section 4: Climate and its Influence on HONO).

4. Applying the CVI Process at Hono

The workshop was held over three days in April 2019 with 36 participants, over half drawn from the local community and the other half including international contributors amongst a diverse array of researchers, experts and stakeholders. Beforehand, participants were invited to a webinar providing baseline information on climate impacts and asked to consider relevant climate drivers and the values associated with the WH property to ensure a common grounding in the issues. The HONO workshop, as detailed in the full report (Day, J. *et al.* 2019), identified three key climate drivers likely to impact the OUV by 2050:

- Sea level change
- Precipitation changes
- Storm intensity and frequency

and concluded that HONO's Combined OUV Vulnerability was High (Table 1.).

Key climate drivers	Sea Level Change	Precipitation Change	Storm Intensity and Frequency
Exposure	Very likely	Very likely	Possible
Temporal scale	On-going	On-going	Frequent
Trend	Moderate increase	Moderate increase	Slow increase
Exposure	Very likely ○○○○●	Very likely ○○○○●	Likely ○○○●○
Sensitivity	High-Very high	High-Very high	High-Very high
Spatial scale	Extensive	Localised	Extensive
Compounding factors	Medium-High probability	High probability	Medium probability
Sensitivity	Very high ○○○○●	Very high ○○○○●	Very high ○○○○●
Potential Impact	Extreme ○○○●	Extreme ○○○●	Extreme ○○○●
Local management response	Moderate	Moderate	Moderate
Scientific/technical support	High	High	High
Effectiveness	Low	Medium	Low-Medium
Adaptive Capacity	Moderate ○●○	High ○○●	Moderate ○●○
OUV Vulnerability	High ○○●	Moderate ○●○	High ○○●
Combined OUV Vulnerability	High ○○●		

Table 1. Rapid assessment of OUV Vulnerability to three key climate drivers identified. Assessed values of exposure, sensitivity and adaptive capacity contribute to derived outcomes for potential impact and OUV Vulnerability (from Day, J. et al. 2019).

The second step of the CVI process is an assessment of the Community Vulnerability to impacts on the OUV of the site. Workshop sessions explored the economic, social and cultural importance of HONO to local residents and organisations, and the resilience of the community to the identified climate vulnerabilities of its OUV. This process concluded that while potential economic, social and cultural (ESC) impacts were high, the Orkney community had a high adaptive capacity that together led to the assessment of Community Vulnerability as Moderate (Table 2.).

Economic	Moderate-negative
Social	High-negative
Cultural	Moderate-negative
ESC dependency	[-] ○●○○ Moderate-negative ○○○○ [+]
ESC potential impact	High ○○●
Economic	High
Social	Moderate
Cultural	High
ESC adaptive capacity	High ○○●
Community Vulnerability	Moderate ○●○

Table 2. Rapid assessment of Community Vulnerability to three key climate drivers identified. Assessed values of economic, social and cultural (ESC) dependency (sensitivity, ranging from negative to positive) and adaptive capacity contribute to derived outcomes for ESC potential impact and Community Vulnerability (from Day, J. et al. 2019).

By distilling the outcomes of the workshop process to a single measure for OUV Vulnerability and one for Community Vulnerability the CVI process is designed to allow a high-level comparison between diverse WH property and help identify the sites and associated communities at most risk.

However, the HONO CVI process also identified that climate impacts would interact with other compounding pressures, such as growing tourism numbers and changes in the patterns of visitation (e.g. the large growth in cruise and other day-trip visitors over the past decade); infrastructure development (e.g. power transmission and renewable energy infrastructure); and changing agricultural and land use practices, including changes that may arise as a result of climate change. These could affect both the ability of the community to adapt and increase the risk to the OUV of the WH property.

5. Conclusions and Next Steps

The HONO CVI was carried out as the Management Plan for the site entered a period of thorough review to develop a new Plan for 2020-25. The CVI results reinforced the need to ensure climate change mitigation and adaptation issues are woven through the fabric of this new plan, and HES propose to repeat a CVI assessment for HONO in five years as part of the management planning cycle. Additionally, formal tabulation of the workshop results could not fully capture the way the process was able to provide a catalyst for wider conversations about climate change, heritage and the WH property across a diverse and group of people and perspectives: this cemented the decision to repeat the CVI approach in the future.

Some key themes and questions emerged from the CVI process and subsequent discussions:

- Participants identified a need for better understanding of how changes in air temperature could impact on the monuments themselves and their settings through resulting changes to plant cover, agricultural practice, wildlife populations, etc.
- Other opportunities for future research were also noted, including a need for better understanding of compounding issues and how degradation of OUV might affect the community.
- It was acknowledged that as we fill these gaps, a future repetition of the CVI process for HONO might produce different outcomes.

HES have also committed to work with management partners at the five other WH properties in Scotland to implement CVI assessments for each site to help understand their potential climate vulnerabilities, engage with their communities, and inform future management. CVI workshops for Frontiers of the Roman Empire: Antonine Wall and Old and New Towns of Edinburgh were scheduled for May 2020 (though now on hold due to the Covid-19 pandemic).The CVI process also highlighted a World Heritage policy issue: there is currently no mechanism for the review of a Site's Statement of OUV, and this rigidity in the narrative fossilises previous management approaches in a key part of the site documentation. A process to allow updates to the "management requirements" section may be worth pursuing, not least as these requirements are likely to change with increasing climate impacts on OUV and subsequently on the community

While the CVI process assessed the vulnerability of the WH property and community to climate impacts it does not and cannot tell us how respond. However, the CVI workshop provided a forum for and identified and/or enabled discussions (some pre-existing) of options to consider for potential responses. Possibilities include changes in management; focused investment in conservation or protection measures; and eventually perhaps managed retreat, or rescue excavation for components of the site, which might become necessary. This raises further questions: what might these choices mean for the community, and what might they mean for the OUV of the Site and perhaps even WH status in the future? What would a truly sustainable future for the management of the WH property look like, taking into account the role of the WH property in the society, culture and economy of Orkney and Scotland? Given that it is impossible to avoid the "baked-in" outcomes of current CO_2 levels, we will have to seek to answer these questions, together with our partners, stakeholders and community. Critically, meaningful action on reducing greenhouse gas emissions and atmospheric concentrations that are the primary cause of climate change must be undertaken urgently to maximise the protection of WH properties and other sites of significance.

Note: This paper was originally drafted before the current Covid-19 pandemic. We do not yet know what social, political and economic changes are still to come, which will persist, and how, or what they will mean. However, they are likely to be profound, and to require similarly deep changes to how we work.

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Session 7: Negotiating Values and Engaging Stakeholders

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Presentations

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Grave Concerns: How burial traditions increase climate risk at medieval Irish church sites

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Environmental impact analysis of wind turbines

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Abstract

The wind energy industry has strengthened its position in the production of electricity throughout the world in recent years. In some countries, wind power production plays an important role in the balance of power generation. Of course, wind power plants have less impact on the environment than traditional fossil fuels. But, as well as everything created by man, wind turbines have a certain environmental impact. It is important to understand and properly assess this impact and strives to reduce it. This is especially important for the areas where cultural and historical objects are located. In Russia, there is a remote Arctic territory - the Solovetsky archipelago, on the territory of which there is a historical and cultural complex included in the UNESCO World Heritage List. In this article the existing experience of analysis of the influence of wind turbines on the environment is analysed.

Keywords – Wind turbines; Environmental impact; Arctic; UNESCO World Heritage Site; CO_2

1. Introduction

Rapid growth in global energy consumption is a consequence of global technological progress. The result of such growth is increasing environmental and climate change. The use of renewable energy sources (RES) is becoming a priority for countries due to growing environmental problems. The development of RES leads to the fact that the stable and effective development of society will be impossible to imagine without the use of environmentally friendly energy sources. Moreover, for many countries, the use of RES is a solution to national security issues, since dependence on countries that own fossil energy sources is decreasing.

The wind energy industry has strengthened its position in the production of electricity throughout the world in recent years. In some countries, wind power production plays an important role in the balance of power generation. More and more new wind parks are built in the world every year.

Most of the territory of the Russian Federation has no centralised power supply. A large number of islands and remote villages have their own isolated power supply systems. The main source of energy for such areas is fossil fuels (most often diesel), which are used in low-capacity power plants. Electricity generation from diesel is very expensive because the fuel needs to be transported over long distances. Diesel-generator sets have a negative impact on the environment due to their polluting emissions. Transportation in harsh weather conditions creates environmental problems associated with an increased risk of fuel spills and leaks. Many diesel power stations have outdated equipment, as a result, they have high fuel consumption and, consequently, higher cost of energy production and more adverse environmental impact.

Wind power generation has great potential in the Arctic and can help solve the problems described above. Of course, it also has certain limitations due to severe climatic conditions. However, with the right approach, harnessing the huge wind potential of northern territories can bring many benefits.

This article describes the case of the Solovetsky archipelago. The Solovetsky archipelago is a group of islands located in the Arctic zone of the Russian Federation (shown in Fig. 1). Solovetsky settlement is located on one of the islands and has a population of about 1000 people. The Solovetsky historical and cultural complex is included in the list of UNESCO's World Heritage Sites. The monastery on Solovetsky Islands was founded in 1436 by monks. In the 16th century the monastery was the richest industrial and cultural center of northern Russia. At the end of the 16th century the monastery became a fortress – it protected the north-western borders of Russia. From the 16th to the early 20th century the monastery was a political and church prison. The monastic life here was renewed only in 1990. Nowadays Solovetsky monastery attracts not only pilgrims, who strive for the sanctuary, but also scientists, writers, and travelers.

Figure 5. Location of the Solovetsky Islands

While the use of wind energy seems undoubtedly necessary, the impact of wind turbines on the environment needs to be studied, especially considering World Heritage Site status. The aim of this article is to analyse modern knowledge about the impact of wind turbines on the environment and humans and to develop recommendations for the case of the Solovetsky Archipelago based on this analysis. In this article the main areas of impact are highlighted. The analysis of modern scientific researches is executed. The Solovetsky archipelago case is investigated.

2. Energy system of the Solovetsky archipelago

At the Solovetsky Islands, the production of electrical energy is currently provided by two diesel power plants equipped with diesel-generator sets with a total capacity of 6.2 MW. The average daily electrical power in winter 2016 was 1440 kW and in summer was 721 kW. The maximum daily electrical power was 1600 kW. The electrical load and, accordingly, the consumption of diesel fuel during the winter period is higher than in summer. This is caused by the fact that electric heating is widespread in the settlement due to the undeveloped central heating system and the prohibition on heating with firewood. The reason for the prohibition is that the territory has World Heritage Site status.

For the isolated energy system of the settlement, this is a case of irrational use of fossil fuel, which is delivered to the settlement only by sea. The difficulty of delivering fuel by the Northern way increases its cost several times. Emissions from diesel generator sets were calculated using operating data on diesel fuel consumption. Gross emissions of carbon monoxide, nitrogen dioxide and sulfur dioxide are shown in Fig. 2.

Increase of energy and ecological efficiency is a necessary way of Solovetsky archipelago development. For this purpose, it is necessary to stimulate the reduction of imported fuel consumption through energy-saving measures and the use of local energy resources, including renewable energy. The archipelago, located in the Far North, has great wind energy potential. Therefore, it allows creating an energy system based on wind power plants.

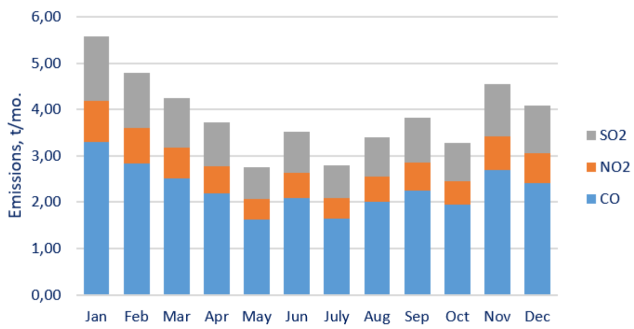

Figure 2. Monthly emissions of pollutants at Solovetsky Archipelago (2016)

Russia has not yet gained enough experience in building wind parks, especially in remote areas. Of course, wind power plants are characterised by a large list of advantages. However, they also have a certain impact on the environment. Therefore, at the design stage an essential point is the assessment of this impact. Solovetsky Historical and Cultural Complex is included in the UNESCO World Heritage List, which in this case strengthens the requirements for environmental impact.

3. Types of wind turbine environmental impact

3.1 Noise pollution

One of the main arguments against using wind turbines is noise. Excessive potential background noise may interfere with the monks, as the World Heritage Site is the active monastery. In addition, the background noise will disturb the perception of the site as many travellers and pilgrims come to the islands to find pacification.

Wind power plants produce two types of noise: mechanical and aerodynamic. Mechanical noise is well studied and understood, can be easily reduced and is usually perceived in the immediate vicinity of the wind turbine. Aerodynamic noise is generated due to fluctuating forces interacting with the blades of the wind turbines. Aerodynamic noise is one of the most serious barriers in wind energy development. Therefore, scientists actively study the mechanism of noise generation to control it effectively [1].

Methods of calculation and prediction of noise level from wind park are developed and validated experimentally [2–4]. Modern numerical simulation methods allow to predict the possible noise level with high accuracy. The study [5] focuses on optimising noise levels in combination with the energy produced by a wind farm.

The noise level of real wind turbines is measured. The study [6] evaluates the noise level emission using real acoustic measurements of a wind farm, while these measurements are also compared with simulation results of two well-known noise emission prediction models. It's concluded that wind turbines are characterised as relatively low noise emission sources, compared to other industrial units or conventional power plants, as the sound pressure level at a distance of 300 m away is almost 45 dB(A), i.e. not a prohibitive value for human activities in the wind farm’s broader area.

The diesel power plant is located in the village and produces background noise. Wind turbines can be located at the distance from the settlement and, as described above, the noise level from them can be determined and calculated. In this way, the background noise level within the settlement can even be reduced, thereby improving the environment of the World Heritage Site.

3.2 Visual impact

In the case of Solovetsky archipelago the problem of visual impact of wind turbines is actual. Visual impact is a subjective factor. However, many large firms employ professional designers to improve the aesthetic appearance of wind turbines. But despite this, wind turbines look futuristic compared to such historical objects as the monastery. Therefore, a rational approach to the design of the wind farm is needed.

Landscape designers should be involved in the creation of the wind park project on the Solovetsky Islands. The project should be coordinated not only with state authorities, but also with the Church.

Wind turbines should be located in a way that does not disturb the historical view. In addition, visual unity must be maintained – the same type of wind turbine, the same height, the same color. Wind turbines must be geometrically correctly positioned in blocks. The number of wind turbines and their height must be limited for the correct visual perception that does not disturb the historical view of the World Heritage Site.

3.3 Infrasound and effects on human

A number of people are reporting an environmental sensitivity to sub-audible windfarm sound (infrasound), characterised by the experience of recurrent non-specific symptoms. A causal link between exposure and symptoms is not indicated by empirical evidence. Research indicates symptoms may be explained by the nocebo response, whereby health concerns and negative expectations, created from social discourse and media reports, trigger symptom reporting.

Studies prove that there's no relationship between wind turbine noise and stress effects and biophysiological variables of sleep [7,8]. The study [9] provides evidence for the role of individual differences and psychological factors in reports of sleep disturbance by people living in the vicinity of wind turbines.

The fact that some inner ear components may respond to infrasound at the frequencies and levels generated by wind turbines does not necessarily mean that they will be perceived or disturb function in anyway [10]. However, the impact of infrasound on humans is still being studied.

3.4 Impact on birds

Another possible environmental impact factor for wind turbines is the death of birds. The Solovetsky archipelago is the nesting area for birds, therefore the impact of wind turbines on birds should be assessed. Incorrect location of the wind park may cause damage to the fauna of the UNESCO protected site.

Studies to assess the impact of wind turbines on bird migration as well as to prevent impact on birds are conducted [11,12]. There are methodological approaches to reduce potential conflicts both in the planning and operation phases of a wind power project. The model simulates bird migration and quantifies the risk of terrain collision. In order to avoid increased negative impact on nature, it is necessary to carefully select the location of wind turbines (avoid migration routes of birds, most common feeding and nesting places), use modern wind turbines, whose blades rotate slower, which reduces the probability of collision with birds. At the moment there are already large ornithological studies of the Solovetsky archipelago, so during the construction of the wind park this information should be analysed.

3.5 Emissions of pollutants

In general, wind turbines have a positive environmental effect. Emissions of pollutants are reduced by replacing fossil fuels. Wind turbines, however, also have a carbon footprint that needs to be assessed and tried to reduce.

Carbon footprint accounting of wind farms is vital for large-scale wind energy exploitation. A huge number of scientific articles are devoted to assessing the life cycle of wind energy projects [13-16]. Carbon emissions from the construction, operation, and dismantling phases are considered in the life cycle assessment of the wind farm. For example, according to research [13] the construction phase accounts for the largest fraction of the total carbon footprint (76.74%), followed by the operation phase (15.32%) and dismantling phase (7.94%).

4. Conclusions

With all the benefits of wind turbines, it is important to assess the impact they can have on the World Heritage Site. The analytical work was carried out to study possible impacts of wind turbines on the World Heritage Site. The most important impact points were identified and analysed: noise pollution, visual impact, infrasound and effects on humans, impact on birds, emissions of pollutants. As a result of the literature and previous studies analysis, the following recommendations can be formulated for the case of the Solovetsky archipelago:

- preliminary assessment of the noise impact of the future wind farm using modern numerical modelling methods should be made. It is necessary to develop a scheme of ideal location of wind turbines relative to each other, taking into account maximum energy efficiency and minimum noise pollution. The background noise level may be reduced by minimising the use of the diesel station and properly implementing wind turbines, that will improve the environment in the settlement;
- it is important to create a design plan and choose the right location of the wind turbines in relation to the Solovetsky Monastery. The project should be coordinated not only with state authorities, but also with the Church;
- preliminary work with residents at the design stage will reduce the possible level of stress exposure and related symptoms;
- using the available ornithological studies of the Solovetsky archipelago bird migration, feeding and nesting routes should be assessed. The use of published assessment models will minimise the impact on the UNESCO protected site.

These recommendations will reduce and prevent negative consequences from construction and operation of the new wind park in the territory of the Solovetsky archipelago.

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Grave Concerns: How Burial Tradition Contributes to Climate Risk at Medieval Irish Church Sites

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Abstract

The tradition of using burial and burial monuments to create lineages and connections to places and people has its roots in the early Neolithic, yet it has survived through prehistory and the early historic period in one form or another and continued into medieval and modern times. In the context of medieval church ruins, the continuation of this tradition results in the clustering of burials around and within the church, the core of the sanctified area. The periodic excavation and maintenance of these family plots weakens the structural remains of these churches and is a major factor in the vulnerability of these structures to the effects of climate changes, particularly increased rain fall, increased storm activity and a longer growing season.

Keywords – Ancestors; Burial; Climate; Relics; Tradition

1. The Cult of the Ancestor

The tradition of reusing monuments for burial has a long currency in the archaeological record. Many of the Neolithic tombs in Ireland and further afield had later burials inserted long after their primary phase of use. The great passage tomb mound at Knowth had been reused for burial as late as the 7th/8th century AD [1] while the early Neolithic portal tombs at Killaclohane, Co. Kerry were extensively reused for burial into the Late Bronze Age, nearly 3000 years after their construction [2 & 2a].

In the prehistoric and early historic periods such reuse was likely to be important in the creation of lineages and origin myths as a basis for the establishment of ancestral rights to territory and resources. The forging of links with 'ancestors' through the appropriation of earlier burial sites/monuments and the physical deposition of bone/s in proximity to earlier burials also had a spiritual significance as part of cultic practise based around the veneration of ancestral remains and spirits [3].

2. The Cult of Relics

The arrival of Christianity in Ireland sometime around 400AD initiated a slow change in religious and burial practise yet the importance of human remains in creating and sustaining lineages and connections remained. The prehistoric ancestor cult was in many respects replaced by the Cult of Relics with the ultimate aim of creating connections to the divine through veneration of the remains of saints and holy men. As O'Brien [4] has put it, 'burial near the bones of the saint became a substitute for burial near the bones of the ancestors' while burial near the remains of the saint, in his role as patron of the kin-group, became an expression of kin loyalty [5].

The veneration of the physical remains of a founding saint are most visibly expressed through the creation of shrines and reliquaries. The 'gable' type shrines recorded in a small number of early ecclesiastical sites in Ireland and most commonly in south-west Kerry, are probably the earliest architectural expression of this veneration of corporeal relics.

Figure 1: Gable shrine at Cill Buaine during excavation showing the fenestella in western side slab through which the 'relics' of the saint would have been touched

The shrine at Illaunloughan was associated with a number of burials, the earliest dating to the second half of the seventh century AD [6] while the shrine on Church Island was also associated with numerous burials and the primary phase was dated to between the late seventh and late eighth centuries AD [7]. Conservation works on the gable shrine at Cill Buaine, County Kerry did not recover any evidence of burial though radiocarbon dating (*Ulex*) indicates that the shrine, with a sub-circular *fenestella* in the slab at the western end through which the supplicant would have touched the bones of the Saint, was constructed between 475-620 Cal. AD making it earlier than those at Church Island and Illaunloughan [8].

A number of graveyards have their origins in this early phase of monasticism and often only the evidence for an enclosure [9], the presence of early cross slabs [10] or the remains of an early stone oratory identifies these as sites that have been in use for burial since the early medieval period yet some of these sites are still in use as graveyards today.

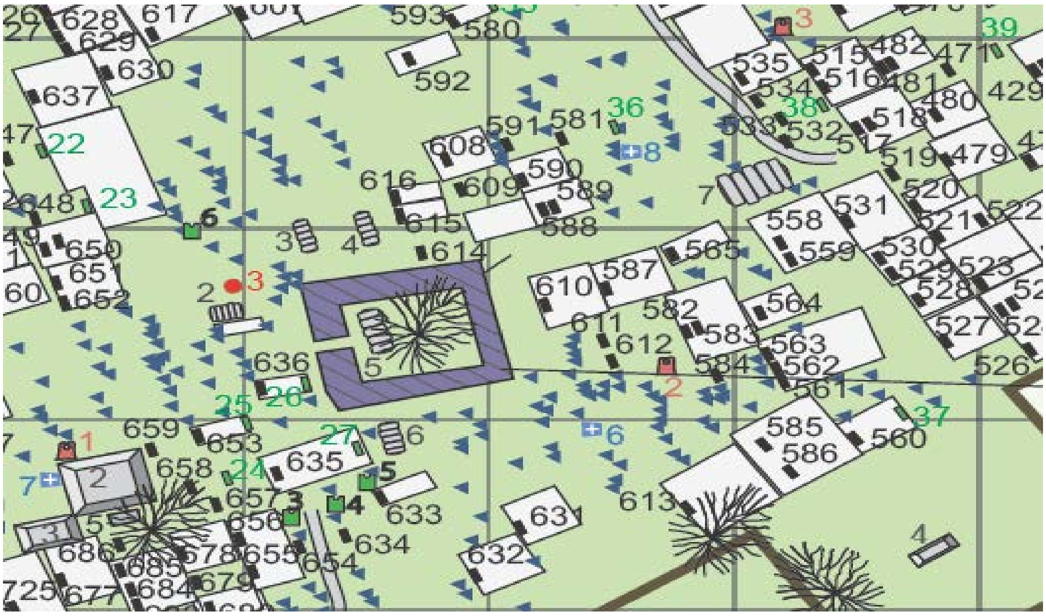

Figure 2: Killavarnogue graveyard near Cahersiveen showing the clustering of older, rough grave markers (blue triangles) around the ruined early oratory

Figure 3: Dún Urlann graveyard with medieval parish church on the left and mounded area of earlier grave markers indicating the likely location of the earlier oratory

3. Medieval Graveyards in Kerry

Between 2007-12 Kerry County Council, in association with the Heritage Council, carried out detailed surveys of the 89 historic/archaeologically protected graveyards in the county. These surveys clearly demonstrated the clustering of earlier graves, often marked by only rough, undressed stones at the head and foot of the burial, around the location of surviving early stone oratories. Indeed, in many cases it is possible to identify the location of a former, destroyed oratory by the clustering of burials.

The introduction of the parish system to Ireland in the 12th century [11] saw the end of the particularly Irish form of monastic church and subsequently saw the construction of medieval parish churches. Some of these parish churches were built within existing, earlier graveyards while others were constructed on new sites. Nonetheless the desire to be buried as close as possible to the church, particularly the sanctuary at the eastern end, and by extension to God (the ultimate ancestor), echoes and in many ways combines the cults of both ancestor and relics.

Many of these medieval churches stand within graveyards still in use today where burials are still interred within existing family plots. Where these plots are within or abutting the walls of the church the excavation and subsequent slumping of ground around the burials destabilizes the structural walls of the church. This in turn leads to loosening of mortar between stones, cracking of wall faces and pulling away of side walls from the gables, particularly in the many cases where the need to associate burials with the church has extended to the removal of dressed corner or arch stones for use in the construction of tombs or headstones.

Figure 4: Churchtown medieval church ruin. Here the corners and the dressed stone around the east window have been robbed for use in tombs while up to 10 burials have been inserted partly under the gable wall

4. The Effect of Climate Change

Such damage to the structural integrity of the ruins leaves them more vulnerable to the effects of climate change [12 & 13], particularly increased rainfall washing out loose mortar and inundating/weakening areas of softer/slumped ground around the foundations; freeze/thaw action within compromised wall joints; storms and increasing wind velocities; longer growing seasons and the increased colonization of walls by plants and grasses.

Figure 5: Grave surround cut partly under side wall at Churchtown causing slumping and cracking of the wall. Note recently fallen stone from the wall face

This combination of damage caused by a cultural tradition extending back to early prehistory and an increase in extreme weather events as a result of climate change has left many medieval churches in an unstable and unsafe condition. Conservation reports compiled on behalf of Kerry County Council for a number of the more dangerous structures have concluded that continued burial within and abutting the church ruins is a serious problem and a major contributory factor to the vulnerability of the structural walls to climate related events.

Indeed, even the maintenance of existing tombs and graves abutting structural walls has become a major issue as this often results in the killing/removal of the ivy that has completely taken over many of these structures and is usually the only thing holding the walls together. This removal of ivy as part of the maintenance of graves also increases the risk of collapse from extreme weather and has resulted in four major collapses of the structural walls of church ruins in Kerry graveyards during the last seven years, all during or shortly after major rainfall events or storms, as observed.

Figure 5: Kilbonane Church which was structurally intact in 2009. The major collapses at this site occurred after an extended period of freezing weather in 2010 and heavy rainfall over the Autumn of 2012

5. Structure or Tradition

Clearly a dichotomy exists between the desire to preserve the structural remains of these medieval churches and the continuation of a longstanding cultural tradition. Many older graveyards have been replaced by modern graveyards, yet people will insist on burying within traditional, over crowded, family plots in the older graveyards. A recent disagreement over the extent of traditional plots within a medieval church led to legal proceedings and a request for permission to disinter a burial so that DNA analysis could be used to settle the dispute. The attachment to these plots and the traditions of burial run deep. Putting an end to the practise would not be easy or indeed well received while policing any embargo on such burials in these mainly isolated, rural graveyards would be impossible.

And what value do we place on the burial tradition itself? Is it of less value than the structural remains of the church? In the end, the people will decide which has more value; we can only ensure they have all the facts to make an informed choice as to which will survive the rigors of time, change and climate, but, as the Irish proverb puts it:

Is treise dúchas ná oiliúnt [13] - Tradition is stronger than learning

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Saving the lodberries of Shetland

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Abstract

Today, there are few remaining lodberries in the town of Lerwick, Shetland. In the early 1800s, the waterfront of the town was lined with over 20 lodberries, serving as homes, shops, and stores for goods. Once used by merchants and smugglers alike, the lodberries reflect the strong connection of Shetlanders to the North Sea.

However, due to their placement on the shores of Lerwick and direct exposure the seas, the few remaining lodberries are vulnerable to climate change. Further contributing to the decay of these buildings are inappropriate repairs and an overall lack of maintenance.

This work is aimed at considering the issues of climate change and the conservation efforts, on-going or needed, to save these unique historic structures. The primary objective is to determine the current risk factors and assess the influences of authorities and private individuals in their conservation.

Keywords – Lodberries; Shetland; Lerwick; community; heritage

1. Introduction

1.1 Aims and objectives

This work aims to briefly examine the importance and present state of a sample of the remaining lodberries of Lerwick, Shetland. It covers the state of the lodberries and the impending risks due to climate change that are of concern for the future of these buildings. In addition to an analysis of the physical state, this work explores current conservation efforts and who is furthering or impeding these efforts.

1.2 Methodology

The majority of research for this work was conducted remotely through online and print sources. The online sources range from local news articles to documents published by local and national authorities. The print sources used include books published locally in Shetland.

In additional to online and print resources, first-had information was gathered from a site visit in 2018 and relevant sources were contacted. This information includes photographs of the buildings in question and notes taken while on site. During this research visit, an interview with The Shetland Islands Council was conducted. Information gathered from this interview has indirectly contributed to this work by giving the author a deeper understanding of the Council's approach to conservation management. To verify information about the ownership and current applications related to some of the sample properties, the Shetland Islands Council and an architect currently working on an application for works to a lodberry were contacted.

2. Development and context

2.1 Location and Geography

Shetland is the most northerly point of Scotland, situated so far into the North Sea that it is closer to Norway and the Faroe Islands than to the nation's capital. The majority of the 100 islands of Shetland are uninhabited by humans but are home to many species of native wildlife [1].

Lerwick sits on the east coast of Mainland, the largest of the islands of Shetland. Its name is derived from a combination of Norse words *leir* 'clay' and *vik* 'bay,' implying mucky conditions of the harbour tucked into the Bressay Sound [2].

2.2 History and settlement

2.1.1 Shetland

The position of Shetland in the North Sea, the rich fishing waters that surround the isles, and the plethora of safe harbours have made it a natural stopping place for many seafarers and settlers. The Norse used it as a contact point between Norway and the Jarldom in Orkney, while the Dutch and Germans were attracted to its resources and trading, and the Scots saw it as an opportunity to expand their landholdings [3].

2.1.2 Lerwick

In its infancy, Lerwick was little more than a shantytown for trade with the fisherman who took shelter in Bressay Sound. With time, Lerwick developed along the waterfront to increase its importance as a trading hub [4]. The area known as Commercial Street became the main street for business and industry. Over the past nearly 400 years, Lerwick has developed into the capital of Shetland, now boasting strong industries in fishing, oil and even tourism. The architecture of Lerwick reflects this connection to the sea and its historical and modern importance. Today, the town is home to over 1/3 of the population of Shetland [5].

2.2 Current climate

The overall climate of Shetland is relatively mild despite is northern location. It is classified as a "temperate maritime" climate. This is due to its position in the Atlantic and the resulting warm temperatures of the surrounding sea. Surprisingly, Shetland boasts a dryer climate than some other parts of the country with an average rainfall of 1,200mm per year. However, wind is nearly constant on the islands. While the average is only about 24kph, it is possible for winter winds to reach hurricane force extremes [6].

2.3 Conclusion

The seafaring history of Shetland and the importance of trade in Lerwick greatly influenced the development the town. The historic buildings that line the seafront, such as the lodberries to be discussed in this work, exemplify Lerwick's mercantile past. Although it is located deep in the northern Atlantic Ocean, Shetland has a relatively mild climate with the possibility of strong winds particularly in the winter months.

3. Significance and current state of Lodberries

3.1 History and design

The lodberries are small groupings of connected buildings that were built to meet the needs of the growing trade and enterprise of Lerwick in the late 1700s and early 1800s. They acted as dynamic hubs for merchants, combining a dwelling, shop space, storage of goods, and a private pier into one compact complex. The lodberries are sandstone structures with lime mortar. Timber is used primarily on the interior of the buildings or to frame windows and dormers. The roofs are finished with slate tiles.

Each lodberry is unique in its design, though they all share the same basic elements. They are designed with a shop and dwelling along Commercial Street and a pier jutting out into the bay for the ease of access to the water. A recorded 21 lodberries were built by 1814 [7]. Their unique designs and importance to trade made them integral to the character of the waterfront and Commercial Street.

This area of Lerwick continued to be the centre of development due to a strong interest in coastal and sea-based industries. The building of the Esplanade in 1886 was a major expansion of the usable waterfront, but this led to the destruction of several lodberries and the loss of waterfront adjacency for some of those remaining [8].

3.2 Current Use and maintenance

One of those that survived this urban development is currently home to The Peerie Shop. The state of this C-listed example is significantly healthier than other lodberries that still retain waterfront access. This is due to regular use and maintenance, as well as reduced erosion from no longer being in direct contact with the sea.

For some other remaining lodberries, the situation is not as promising. Although it is not listed on the BARR, the B-listed lodberry located at 2 Commercial Street, known as Copeland's Pier, is at the centre of controversy in regard to its use and habitability. It is owned by the Shetland Islands Council and was previously used by the Lerwick Sea Scouts as a base until 2016. As recent as January 2020, the Scottish Environment Protection Agency (SEPA) has expressed concerns about the flood risk of the property and it is reported that the interior is in poor condition. It is currently unused [9]

The lodberry at 20 Commercial Street, known as The Lodberrie, is a high-profile building along the waterfront. This A-listed building has been on the Buildings at Risk Register for over

10 years, with reports of “significant” and “accelerated” masonry decay [10]. This masonry decay was evident during a site visit conducted in July 2018. It is listed as being in private ownership and only partially occupied [11,12].

3.3 Conclusion

The lodberries were pivotal for the success of trade for the local merchants of Lerwick. Their unique architecture has continued to define the character of the waterfront and Commercial Street. Unfortunately, most have been lost to later periods of development. However, the current state of the remaining lodberries ranges greatly. While some examples are no longer seafront-adjacent as they were originally designed, others still retain their waterfront position. Those that are in contact with the water are currently at greater risk of accelerated stone decay and flooding.

4. Risks and conservation efforts

4.1 Climate change risks

Due to their proximity to the sea, the lodberries at Copeland’s Pier and The Lodberrie are especially vulnerable to issues caused by climate change. Both properties are facing rapid stone decay and heightened risks of flooding. As properties that are in direct contact to a rising sea, wetter seasons, and strengthening storms, the lodberries are at extreme risk.

The sea level is projected to rise by 3mm per year [13]. Flooding has been a reported issue for Copeland’s Pier [14], and with increasing sea levels, there is a greater risk of flooding. Authorities have expressed concern over the potential risks to inhabitants should the building be occupied, including the Scottish Environment Protection Agency (SEPA). The current level of the building floors is 1.615m Above Ordnance Datum (AOD), however considering the projected sea level rise, the recommended minimum level is 2.886m AOD. Additionally, the property is only accessible from the pier that is exposed to high tide and waves. With increases in storm surges, the use of this access point is not deemed to be reliable or safe [15].

The Lodberrie is at an increased risk due to improper repairs that heighten the rate of decay when compounded by wetter weather and rising sea levels. The increase in rainfall in both the summer and the winter by at least 12% in the past decade [16] creates moisture issues for the entirety of the building, not only the lower sections in at the water level. The use of cement, rainwater goods in poor condition or missing, slipped and missing slates, as well as issues with rooflights have all been reported for this property over the past 12 years [17]. During a site visit in July 2018, these listed maintenance issues were observed. Stone decay just below the roofline was documented at the time and shows a great deal of erosion compared to the surrounding cement pointing. This is directly related to the lack of rainwater goods and the increasingly wet climate.

4.2 Current conservation efforts

Neither of the lodberries mentioned in this section are currently undergoing active conservation works. The Shetland Islands Council currently owns Copeland's Pier. Although there are no current active works to this building, there have been recent applications for a change of use to allow for it to be used as a dwelling [18]. This application has been refused as of November 2019, but the applicants have the ability to appeal if they so desire. Comments on this application by various authorities and organisations are greatly concerned with safety of the property in regard to flooding. Therefore, future applications would most likely require extensive proposed works that would reduce flooding risk.

On the other side, The Lodberrie is privately owned and occupied. There is no evidence of recent repairs or current works. Although it is A-listed, meaning it has been deemed of national importance, the private owner has full responsibility of maintenance and repairs [19].

4.3 Conclusion

While the lodberries discussed in this section are at high risk due to poor maintenance and climate change, there are currently little to no efforts towards their conservation. The difficulty in this may be due to their vulnerable positions, but there are also growing concerns about the feasibility of the ability to future-proof these buildings against rising sea levels and wetter weather conditions.

5. Concluding Observations

5.1 Prominent Influences

As it stands, the most concerted efforts for the maintaining of the lodberries are by private individuals. This is either by their use as businesses, through occupation and private ownership, or through the proposal of alternate uses. However, because the 3 lodberries mentioned in this work are all listed and within the Lerwick Lanes conservation area, they are protected by national and local policy. This means that local authorities must approve any works that may impact their character.

Some local organisations are active in this area and have been involved with previous improvements. Living Lerwick and the Lerwick Community Council have invested interest in the economic viability of the town centre and the retention of build heritage.

Ultimately, the financial and logistical burden of conserving such vulnerable properties may prove to be too much for private individuals, especially as climate change increases the risks associated with being in direct contact with the water.

5.2 Uncertain Future

As this work has illustrated, the future of some of the lodberries may be difficult to predict. In particular, Copeland's Pier and The Lodberrie are exceptionally vulnerable to a lack of maintenance, flooding, and increasingly wet and tempestuous weather.

Copeland's Pier is a case of finding an appropriate use that is not put at risk by the flooding of the lower levels. Although the council has not approved the proposed use as a dwelling, and by extension deterred the purchase by private buyers, it is ultimately responsible for the retention and conservation of the property. As the council has allowed the use of the building by the Sea Scouts in the past, there is precedent for non-domestic use of the property. However, in addition to flooding, the lack of an entryway that is not susceptible to high tide or unruly waves creates further issues of how the building can be used while maintaining the health and safety of those who occupy it.

If The Lodberrie is to be conserved, there must be pressures put on private owners to take the responsibility of carrying out necessary works. The lack of maintenance at this specific property has been a major issue in the exacerbated decay caused by climate change. Improper repairs made in the past have begun to prove detrimental to the historic fabric when combined with a lack of rainwater goods and progressively worsening climate.

The greatest question is whether or not it is possible to save buildings with such direct exposure to risks that are so difficult to control or moderate. As mentioned previously, the flooding risk at Copeland's Pier is so significant, authorities have refused habitation of the lodberry. With a projected possible sea level rise of over 1m by 2100, the viability of using these buildings significantly decreases [20]. The financial investment in flood barriers or the engineering of structures to impede flooding would be great. The even more pressing question is who should shoulder this financial responsibility.

5.3 Opportunities

While the prospect of saving the vulnerable lodberries of Lerwick seems restricted and unclear, they may be prime examples for learning and teaching about the impacts of climate change on coastal heritage. There is obviously interest by individuals in these unique pieces of the history of Lerwick, as illustrated by their use by businesses, local groups, and private parties.

Through educational and professional opportunities, the lodberries could be case studies for research surrounding the decay of stone, engineering to reduce flood risks, and other areas of study related to conservation and climate change. They could also serve as projects related to traditional building repair and coastal architecture.

To support the occupants and owners of these buildings, improvements in grant applications and finding assistance for proper repairs would be vital. This should be done on a local and national level in order to improve funding opportunities.

Ultimately, the lodberries are at a pivotal point in their history. They provide a link to the sea and seafaring that has been a large part of Shetland's development over the centuries, but now they are threatened by the island's shifting climate. Those that survived 200 years of redevelopment and the sea deserve attention and serve as a reminder of the impacts of climate change on our built heritage.

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Bartjan – climate change and the effects on sámi cultural heritage sites

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Abstract

Sámi cultural heritage sites are under great threats from climate change and its effects. This report discusses the use of schemes and instruments for monitoring and planning for the effects in relation to traditional, indigenous people's beliefs of nature as giving and taking. According to the sámi people preserving culturally important constructions or land are important but are subject to the preservation of the stories, myths and knowledge that are carried by them. Nonetheless, sámis and sámi organisations need to acknowledge the need for monitoring and strategically plan for the long-term maintenance of their cultural heritage sites.

Keywords; cultural; heritage; climate; change; indigenous

1. Prelude

Sámi cultural heritage sites are under great threats from climate change and its effects. This report points to the traditional sámi perspectives of nature and its ongoing changes challenging general views on climate change effects. Preserving sámi cultural heritage sites and fight climate change effects are important, but measures should be focused on the importance of the immaterial cultural heritage values that are being channelled through preserving the others.

2. Introduction

Day by day climate change and its effects become more evident. Higher temperatures on land and in water, extreme storms and rain, less snow or unexpected growth are signs of changes affecting our environment. Climate change affects us all, mankind, animals but also nature and cultural environments.

From 2017 to 2020 partners and associated partners in Norway, Scotland, Iceland, Ireland, Russia and Sweden are running the project "Adapt Northern Heritage", funded by the Interreg programme for the Northern Periphery and Arctic. The purpose of the project is to find usable tools to handle the effects of climate change on cultural sites and establish long-term action plans.

2.1 Background

In general, our knowledge about climate change and its effects is good. Official reports pinpoint the fact that our knowledge must be combined with action plans in order to avoid changes and its´ effects. Some of these mention the need for knowledge of indigenous peoples to be highlighted, stemming from their close relationship to nature and its resources. One example is the climate action plan of the Sámi Parliament in Sweden.

Our knowledge about how cultural environments and sites are being affected by climate change are to some extent limited and need further research. Sámi cultural sites, where sámis believe material and biological cultural heritage combine with immaterial heritage to form a holistic system, have similar but perhaps greater challenges in this regard.

As part of the project, the purpose of the workshop was to examine the effects of climate change on a sámi cultural site and develop knowledge of how to avoid or, at least, handle them in the future. Bartjan, summer site of Tåssåsen sámi village, was chosen as a study object with the ambition to evaluate the model for evaluating climate change presented by the project and to answer the question if the model would be applicable on sámi cultural sites.

2.2 Cultural heritage values in a sámi definition

Samis consider cultural heritage as a holistic system where the different parts interact and are dependent on each other. "Culture and history of the sámi people in a geographical context" is the official definition of cultural heritage of the Sámi parliament. In the definition they stress the following aspects of cultural heritage;

- Material cultural heritage; all physical remains and traces in nature such as buildings etc.
- Immaterial cultural heritage; traditional knowledge, stories, myths etc.
- Biological cultural heritage; proof of usage of nature, such as banks for reindeer herding etc.

2.3 Workshop

In August 2018 a workshop took place in Bartjan. The ambition of the workshop was to test the model of analysing risk and vulnerability in relation to the cultural site presented by the project. The group early on realised that a model to a great extent focusing on visual inspections cannot fully grasp the conditions residing in sámi cultural environments. Hence, the group decided to perform a "walk and talk"-workshop where we would wander the area discussing our findings upon which we would base our evaluation.

3. Bartjan

3.1 The place

Bartjan is situated just below the mountains in the southwestern part of Jämtland on the border to Härjedalen. Bartjan is defined as a cultural environment of national interest in Sweden and serves as the summer site of the sámi village Tåssåsen. The history of the site is being told by findings of old banks for reindeer herding and milk pits. In the middle of present buildings and traditional tipis old tipi plots tells stories about former inhabitants. Nearby there are several reindeer herding fields, some of them still in use, some deserted long ago. The name Bartjan comes from the south sámi word "barsje" meaning "edge of the mountain" or a place where you can see both mountains and the forest.

3.2 Cultural heritage values

When discussing the cultural heritage values of Bartjan we use the definition of sámi cultural heritage values of the Sámi parliament; "Cultural heritage reflects the past but is at the same time the basis for a philosophical system and the living culture of the sámis".

3.3 Material cultural heritage values

In Bartjan a variety of constructions from modern huts to traditional turf tipis can be found. All of them bear witness of the particular style used at the time when constructed. Most of the tipis are for living, but tipis for storage of goods as well as for animals such as goats and horses can be found.

3.4 Biological cultural heritage values

Adjacent to the site there are fields for grazing and active reindeer herding. There are though no established facts about the history of Bartjan and its usage. Ancient remains such as tipi plots and milk pits in the area close to existing buildings tell us about long presence of sámis.

3.4.1 The springs

The main reason for the site being established in this very place was the existence of springs. These are conditions for everyday life as they support inhabitants with water to drink, for washing etc. Presently, there is one functioning spring and one that is under renovation.

3.4.2 The freezer

During parts of the year, snowdrifts close to the site can be found. These act as freezers and are fundamental for storing food.

3.4.3 Immaterial cultural heritage values

Based on the holistic view of the sámis, discussions about effects of climate change needs to take immaterial cultural heritage values into greatest account. Environmental and physical changes lead to changes in behaviour within the community which can affect the supply of sources of traditional knowledge or of the site as a means for keeping and telling important stories.

3.4.4 The stories

A site and how people relate to it is fundamental for supporting stories and knowledge that are important to individuals or the group of people. These stories contain important events, memories of people or transfer myths and beliefs between generations of people. To a great extent, the stories are the glue that keeps people together.

3.4.5 Traditional knowledge

In the sámi society the importance of keeping and transferring traditional knowledge to younger generations is often stressed. In this sense, all stories are traditional knowledge through which knowledge of traditional land use, technique, the reindeer and nature as a whole etc. are being transferred to peers and children.

3.4.6 The language

Language and the use of it is strongly related to traditional knowledge and the immaterial cultural heritage. In traditional words and sentences there are meanings, interpretations and nuances that face a risk of disappearing unless they are used in traditional settings and in relation to real conditions and events.

3.5 Climate Change

Bartjan is a site under constant change. While change is difficult to appreciate while occurring, we face a challenge in relating these changes happening now to climate change and not only to natural degeneration. Current knowledge will alert us to these effects as well as to help us understand changes that already have occurred. These changes mainly involve growth of trees and bushes etc. in new and formerly unsuitable environments, such as on higher altitudes. Nowadays, not only the mountain birch can be found on the slopes of the mountains, but also pine and spruce. These effects of climate change have gradually changed how the site has been used.

3.6 Current Status

Some twenty years ago Bartjan was in a bad shape. A need for saving and restoring the environment and the structures was appreciated and a project for renovation was started. During the following years the constructions were renovated, and the site cleared of bush wood and other growth. Nowadays, the members of the sámi village continually work on keeping the constructions in good shape and the area cleared leading to different cultural findings now being openly visible. Maintenance of the springs, along with construction of new buildings, are simultaneously being undertaken. Today, the site Bartjan is in good shape. Mainly, it is used during the calf marking in the summer.

3.6.1 Current status of climate change effects

General signs of climate change can be found also in Bartjan;

- Higher temperatures; people related to Bartjan note that temperature is under constant increase. Snow pits previously prevalent in the area are now rare leading to challenges for storage of food as well as for the reindeer finding cool.
- Extreme weather; according to the same testimonies the weather is believed to be changing between extremes.
- Constant variations of temperature from high to low affects snow quality and thus the access of the reindeer to grass and other pasture.
- More often extreme winds are being experienced.

- Changing conditions for growth; observations tell of changing conditions for growth. Nowadays the pine can be found in previously non-auspicious altitudes.
- Insects; changes in climate lead to improved conditions for (new) insects affecting both the growth and the reindeer. Recently Bartjan have been exposed to a worm feeding on the mountain birch leading to the trees to a great extent being deprived of its leaves.

3.6.2 The sámi perspective

In sámi culture people show great respect and live for, by and with nature and its resources. Sámis have their own view upon and their own relationship to all changes in nature. For sámis it is natural and a tradition that a tipi after decades of usage or areas deemed surplus or unusable are abandoned and left to go back to nature to regain its original status. According to sámi tradition descendants must not be limited or disturbed by remnants from previous generations but have the same conditions and possibilities.

Reindeer herding sámis are subject to conditions affecting the reindeer and how it can handle changes in nature and among other animals. The reindeer, as most animals, are dependent on habitual patterns and prefer stable and reliable conditions. It gives birth in the very same area as it was born, it grazes in the same areas, it moves between areas in the same paths etc. If these habitual patterns need to be abandoned it changes the conditions, not only for themselves, but also for the reindeer herders and the sámi village as a unit. This could lead to the sámi village abandoning a site leaving cultural heritage values and the constructions to go back to nature.

From these perspectives, sámis need to address climate change and its effects in their own way, free from systematisation and schemes. Changes, that in western interpretations are vulnerable threats, can according to sámi traditions, be seen as natural changes and conditions to handle over time. According to this, the risk- and vulnerability analyses must be handled and interpreted differently.

3.7 Vulnerability

Bartjan as a cultural heritage site will be susceptible to climate change and its effects on the area's natural resources, traditional structures and growth in general.

3.7.1 Springs running dry

Access to water is fundamental for a sámi site to work. Bartjan is surrounded by streams, rivers and lakes but the distance to them is long. The springs within the close area have therefore been very important and the reason for choosing this very place for the site. The springs gives water for drinking and washing. Climate change can lead to changes in conditions such as increasing temperatures or changes in rainfall. There is risk this will lead to drought leading to the springs drying out and disappearing. If the springs were to disappear the conditions for the site would change leading to negative consequences for constructions and the environment.

3.7.2 Constructions degenerating

Traditional constructions are sensitive to extreme weathers as well as increasing temperatures and moisture. Thus, climate change is a threat. The sensitivity of the constructions are not only about direct physical threats, they can also be indirect, whereas less usage due to other factors leads to lack of maintenance and a subsequent degeneration. For example, climate change can change the behaviour and movement of the reindeer leading to an area being abandoned, which in turn leads to a need for the reindeer herder to change his or her behaviour. Subsequently, the usage of a site like Bartjan and its traditional buildings would decrease leaving the buildings open for attacks from moisture and mould.

3.7.3 Growth intruding

Increasing temperature and other climate related changes will lead to new conditions for the site Bartjan. The area has been, is and will be subject to intrusive growth in the form of new types of vegetation, but also in the form of densification. Hence, biological cultural heritage values are under threat. Formerly used banks for reindeer herding, milk pits and bone hides face a risk of being hidden under increased vegetation. Being hidden, the stories based upon them could be forgotten leading to the risk of younger generations within the sámi village not getting the knowledge or being able to transfer these stories further. In this sense, the sámi village faces a risk of losing the history of the site. Therefore, they are required to make sure the site is being used regularly as well as establish a plan for regular maintenance.

3.7.4 What is left to tell?

The Sámi parliament defines cultural heritage as holistic (see above). This can be interpreted as the physical cultural heritage being important, but that its value increases through the philosophy, the knowledge and the stories that it carries and canalises. It is in the light of this meaning that sámi cultural heritage values and the risks that they are subject to must be seen in a bigger perspective. With deteriorating physical cultural heritage values the stories risk losing its connection to a place and not being remembered and told any more. Knowledge about the lands, the people and important events can disappear. Local, sámi traditions are at risk of disappearing. Transfer of knowledge, so often stressed in sámi needs analysis, must be appreciated being under stress from climate change and therefore be strongly considered when discussing effects on sámi society of climate change.

3.8 Action plan and need of resources

Preservation of sámi cultural sites means preservation of sámi culture and traditions. On the bases of the effects of climate change on Bartjan we discussed what measures were needed to preserve and protect its cultural heritage values.

3.8.1 Material and biological cultural heritage values – use, maintain, restore

In our workshop we concluded that material and biological cultural heritage values such as traditional buildings and other environments risk damages and degradation under limited usage. Thus, one measure should be to make sure that these cultural heritage values actively are being used so that damaging elements cannot develop in these structures. Using the site, its constructions and the environments practically means living the stories and the myths and transferring the knowledge. This way, history is kept alive.

Secondly, the action plan should plan for measures involving active maintenance of structures and the environment. The sámi village has directed the responsibility of history, traditions and culture to a certain individual. In his responsibilities must be included such actions.

Thirdly, the sámi village can plan for restoring the cultural heritage values. These needs should not arise if previous actions in the plan have been performed accurately.

As mentioned earlier, climate change might lead to the reindeer moving to areas where the conditions for finding pasture or cool or avoiding insects are better. Reindeer moving away means that the natural reasons for using the site disappears. In accordance with this, plans for how to avoid damages and degradation through active usage must be made. One could argue that this means additional work for the sámi village for which there are no resources and that the society should make such available.

3.8.2 Immaterial cultural heritage values

Protection of other cultural heritage values leads to protection of immaterial cultural heritage values. Measures taken for the protection of other cultural heritage values are, therefore, also automatically measures for the protection of immaterial cultural heritage values. Usage of the site stimulates people to tell about the place, the people and the events. In the action plan for the immaterial cultural heritage values the term "usage" should be stressed.

The action plan should also focus on;

- Documenting; a vivid cultural environment carries stories and knowledge. Active measurements are needed and should involve documenting old stories about the environment, the people and the events so that they can be transferred to younger generations. Tåssåsen sámi village has to some extent acknowledged this responsibility through publications made by themselves and the foundation Gaaltije.
- Conveying; it is important that the stories and the knowledge is being conveyed to members of the sámi village but also to other people and organisations related to the site. Stories and knowledge preserved by younger generations means that both the material and immaterial cultural heritage values are being protected from extinction. Knowing about the stories creates an interest among younger people to take a future responsibility for the site and for the stories and knowledge to live on in the future.
- Making available; in the action plan there should be measures for making the immaterial cultural heritage values available to the public. Making available could be a means for spreading knowledge about the immaterial cultural heritage values to people and organisations outside of the sámi village leading to shared interest and responsibility. The idea is controversial though as there are different views within the sámi society about to what extent sámi stories and knowledge should be spread to the public.

The different measures mentioned above require resources presently not available within the sámi village or the sámi society. Resources made available through the Sámi parliament and other authorities are welcome but need to be complemented.

4. Summary

Sámi cultural heritage sites are under great threats from climate change and its effects. Based on culture and traditions differences in perspectives on nature and the changes occurring means different assessments of the climate change effects and the measures needed to adapt. According to the sámis preserving culturally important constructions or land are important but cannot be separated from the preservation of all the stories, myths and knowledge that are carried by them. None the less, sámis and sámi organisations need to acknowledge the need for monitoring and strategically plan for the long-term maintenance of their cultural heritage sites.

Session 8: Managing Loss

Session chair

Cathy Daly, University of Lincoln, England

Presentations

An assessment of the impact of coastal erosion on the availability of marram grass for thatching on Tiree

Kim de Buiteleir, Argyll & Bute Council, Scotland

Adaptation and relocation of built heritage: what can we learn from the urban transformations of Swedish mining towns?

Andrea Luciani & Jennie Sjöholm, Luceå University of Technology, Sweden

Museums and community engagement of sites at risk through virtual reality

Alan Miller, University of St. Andrew's, Scotland

Dunbeg Promontory Fort and Medieval Settlement site, Co. Kerry: the archaeological management of retreat and loss

Connie Kelleher, Department of Culture, Heritage

Thatching on the Isle of Tiree

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Abstract

Tiree is in the highest category of Annual Relative Sea Level Rise, at over 6mm per annum and Scottish Natural Heritage (SNH) have identified this as one of the habitats most likely to be affected by climate change. Marram grass from the sand dunes was traditionally used to thatch roofs on Tiree. With the growing concern of sea level rises and coastal erosion there are questions over the negative impacts of using this material as the marram helps to bind the sand and form stable dunes. There are now only seven cottages on Tiree still roofed in marram. Due to climate change factors, consideration needs to be given to the future management of thatching on Tiree. The aim of the study is to allow the future development of Argyll and Bute Council planning guidance which will set out adaptation measures for the future of these thatched buildings.

Keywords – Tiree; marram; thatching; coastal erosion

1. Introduction

1.1 Context and Aim

In April 2017 and then subsequently in September 2018 Argyll and Bute Planning Authority granted planning permission for listed buildings which had traditionally been thatched in marram grass, to be thatched in imported Errol Reid [1] [2]. The Architect behind both these proposals, Michael Holliday of Roots Architecture, stated that there was not sufficient marram on Tiree which could be sustainably harvested to thatch these buildings as the marram is needed to protect the dune system from sea level rises caused by climate change [3].

Holliday confirmed that this assertion was based on anecdotal research [3] however research by the Adaptation Sub-committee (ASC) and the Marine Climate Change Impacts Partnership (MCCIP) qualify this, indicating that increased precipitation and severe storms leading to flooding and erosion are among the biggest risks caused by climate change in Scotland [4] [5] [6].

Professor Stewart Angus of Scottish Natural Heritage (SNH), confirmed at a meeting with Historic Scotland (now HES) in 2012 that coastal erosion is strongly linked to the removal of marram grass from the dunes [6]. However more recent guidance by Historic Environment Scotland (HES) states that “Marram grass is an ideal thatching material for the Hebrides as it can withstand strong winds and scouring from wind-blown sand. Imported materials are not naturally adapted to the climate and tend to perform less well. Thus, the local material tends not only to be the most aesthetically pleasing but also the most durable.” [8]

Due to the rarity of thatched houses and the uniqueness of these on Tiree which demonstrate effective adaptation to such an exposed climate [9] it is considered that research is required to understand if a solution can be found for the remaining seven marram-thatched cottages which best protects their heritage, whilst allowing suitable climate change adaptation and management measures to minimise future coastal erosion.

In addition to considering the question of whether marram can continue to be cut for thatch, this research considers the merits of potential alternative thatching materials, as well as setting out what further work requires to be carried out in order to develop planning guidance which will form the basis of future decision making.

1.2 Limitations of The Study

Much of the evidence which forms the basis of this study is anecdotal but is from discussions with members of the local Tiree community and is therefore considered to be of key importance. Furthermore, the MCCIP confirm that despite the data available it is still difficult to fully assess the impacts of climate change on coastal habitats [5].

2. Methodology

2.1 Research Topic

The research topic can be defined as:

The development of planning guidance to form the basis of planning decisions that balances the overarching need to manage the impacts of climate change on Tiree's coasts while allowing a solution that protects and enhances the special characteristics of the vernacular architecture of Tiree

This study forms the preliminary stage of this, in terms of gathering the existing background data. A future step, in collaboration with HES and the local community, is to use this technical paper to implement monitoring of the data as well as the development of planning guidance which can be used by planners as well as members of the public.

2.2 Research and Data

The initial research is based on a series of interviews with owners of thatched cottages on Tiree. Discussions have also been had with bodies with specialist knowledge such as Scottish Natural Heritage (SNH) and Historic Environment Scotland (HES), as well as a review of relevant literature, to compile qualitative data. It draws on a previous preliminary study by Argyll and Bute Council with SNH and HES in 2012 which was not concluded. The second part of the research is the collection of quantitative data in terms of coastal erosion data provided by the Dynamic Coast project [10] in order to start to assess the environmental impact of climate change on the availability of marram for thatched cottages.

3. Results

3.1 Climate change and coastal erosion

Tiree is the most westerly of the Inner Hebrides with a very flat topography. It is in the highest category of Annual Relative Sea Level Rise, at over 6mm per annum and SNH have identified this as one of the habitats most likely to be affected by climate change [11]. Rising sea levels and storms are causing an impact on the sand dunes and causing around half a metre of machair[1] to be eroded annually on Tiree [12]. Simons states that "a recent UN report singled out Scotland's machair grasslands as one of the world's habitats most at risk from climate change" [12].

A particularly severe storm occurred in January 2005, destroying hectares of machair [5] [14] [15]. The MCIPP expect that the frequency of serious storms such as this is likely to increase [5]. As a result of storms and sea-level rise, coastal erosion is expected to increase in coming decades [5] [16] [17].

In 2005, Argyll and Bute Council part funded the capture of LiDAR (Light Detection and Ranging) which includes most of Tiree. The data is compiled by CREW (Scotland's Centre of Expertise for Waters) as the Dynamic Coast Project and maps the position of the mobile shoreline between 1890 and 1970, and 1970 and modern day. From evaluation of the coastal type, erosion predictions have been mapped to 2050 and 2100. This study uses the 2100 projections to compare to areas of marram grass [18].

3.2 The significance of marram in preventing this

In terms of the evidence base of marram's role in the coastal erosion of Tiree, there have been no quantitative studies. However, SNH Coastal Ecology Manager Professor Stewart Angus stated that "while I cannot categorically state that this caused erosion, the period of house building using marram for thatch and baskets etc coincided with times of very high sand mobility in these islands. Authentic conservation of built structures might thus at times be in conflict not only with nature conservation objectives but heighten the vulnerability of the coastline to climate change" [11]. Christina Bell, local SNH Officer, expressed similar concerns in 2011 to Roots Architecture that cutting the significant volume of marram required for thatching a (new) roof would cause long-term damage to the dune system [3].

There is disagreement between potential benefits vs disbenefits of cutting marram (for thatch). Historic Scotland (now HES) and Hannah Morrison, Planning Officer of Western Isles Council, believe that cutting the marram allows it to grow thicker and stronger than previously [19] [20]. On the other hand, SNH advised that the extensive cutting of the marram "can allow the roots to be buried beneath shifting/blowing sands which can impede growth" [6].

A further debate is *when* the marram should be cut. Local Tiree thatcher and thatched property owner Mark Beese advised that for use as thatch the marram cannot be cut until the seed has gone, so from November onwards over winter [21]. The advice from SNH however is that "cutting in winter would reduce the ability of the plant to trap sand at the time when sand

[1] definition of machair – Machair is the fertile low lying grassy plain, found only on exposed west coast areas [13], in which marram plays a significant role in maintaining a defence between the sea and the machair [14]

interception is most needed" [11] and that to minimise environmental impact, if marram is cut it should be done in summer.

3.3 Analysis of dynamic coast captures in relation to key marram areas

Key areas of marram have been mapped in Fig. 1. The seven areas have then been captured using the Dynamic Coast data [Fig. 2] to determine the vulnerability of each area. The data shown includes the projected area of erosion in solid red (or alternatively in the cases of areas 2 and 5, accretion in solid green).

From this mapping, it can be seen that, the following areas of marram will be fully eradicated by 2100: 3, 6 and 7; the following areas will be adversely affected by 2100: 1 and 4; and the following areas are expected to experience accretion by 2100: 2 and 5

SNH warn that these maps are based on linear projections of current trends and do not take into account acceleration or widening of erosion caused by climate change. Resultantly these may be an underestimation of the future position [17].

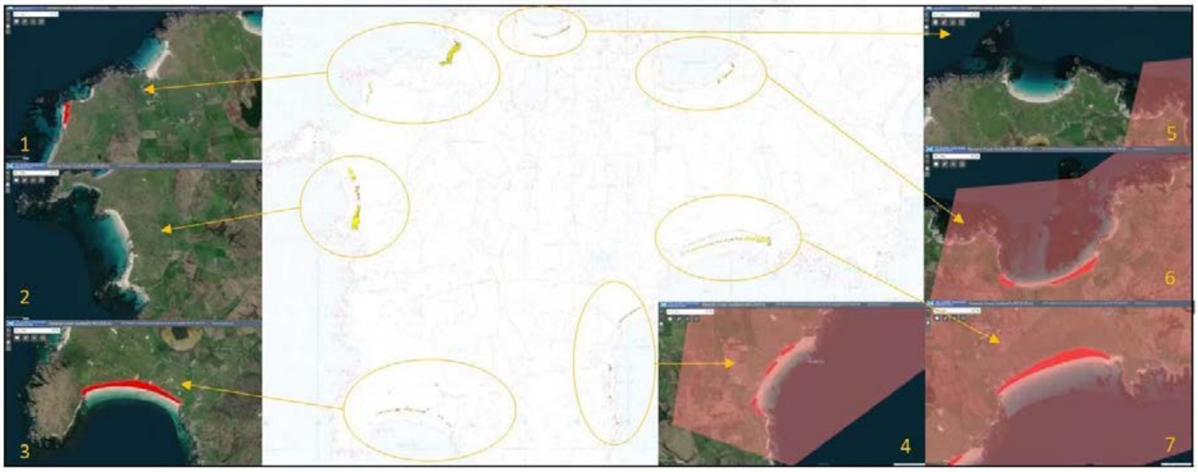

Figure 6. Map of western Tiree showing Dynamic Coast captures of projected coastal erosion (or accretion) by 2100

3.4 The history of thatching on Tiree

The argument to allow only marram for the rethatching of Tiree's listed cottages comes from the point of view of replacing a historic material like for like. However, there is no evidence to suggest that marram was always historically the only material used for thatching on Tiree. In his 1985 book James Souness (former employee of both ABC and Historic Scotland) states that prior to WWII straw was used [22].

Furthermore, in terms of the argument against importing materials, local thatched cottage owners Mark and Jo Vale point out that Tiree would never have been self-sufficient in building materials [23], for example timber has always had to be imported. That said, the *distance* they are imported may be the important factor here.

Perhaps more important than the particular material used, is the form of the roof, as this is key to withstanding the strong Hebridean winds [23] [24]. Sharp angles are avoided, both at the ridge where the thatching material is continued over the top without interruption, and at the hipped end, which has 3 or 4 timbers to give it the curved shape [21]. A further feature of Hebredean thatched cottages is the exposed wall head to prevent wind uplift.

3.5 Tiree today

There are now only seven cottages on Tiree still roofed in marram which need to be maintained regularly. Following approval of recent planning applications [1] [2] there are also 2 buildings now roofed in imported errol reed.

There is less marram available for thatch than there used to be, attributed to cattle overwintering on the sand dunes which eat, crush and destroy the marram [21] [25].

4. Conclusions

4.1 Coastal erosion and marram

The Dynamic Coast mapping provides information on the current position of the coastline, as well as linear projections to 2100. Further data is expected to be available incorporating the effects of climate change later in 2020 [17]. In addition to utilising the Dynamic Coast information, future adaptation and management strategies should be based on a cyclical programme of local monitoring and recording [26].

4.2 Alternative materials

Taking into account the decrease in availability of marram it may be that this is no longer a suitable material in terms of the ethos of a vernacular building. This is on the basis of advice from Historic Scotland (now HES) [19] which discusses that the materials used for thatched roofs inform us of the local conditions at that point in time. On the basis that local conditions are changing as a result of climate change, it may be more responsive to allow alternative, potentially local, materials.

The argument put forward by Roots Architecture for the use of reed is that it will be longer lasting [24] however local thatched cottage owners Mark and Jo Vale point out that, whilst 15 years may be expected from a reed roof elsewhere, there is no evidence yet how long a reed roof will last on Tiree [23]. Walker et al. suggest that imported thatches may fail in less than 5 years [25]. Furthermore, the form is significantly different and may therefore not be as resilient to strong winds.

Conversely marram is a good thatching material for west coast areas as it is very robust in the marine environment. Should an alternative to marram be required a locally sourced alternative is more likely to be suitable for the local climate and is a more rational response than sourcing an imported material for visual continuity [20]. Jessica Hunniset-Snow from HES suggests that straw thatch may be a viable alternative [8].

What clearly *is* important in terms of the materials used is their resilience to climate change, both in terms of the performance of the materials themselves and their form.

4.3 Future work

It is anticipated that the conclusions of the study will be further developed to form planning guidance which will set out adaptation measures for the future of these thatched buildings.

The aim of the planning guidance will not be to dictate what may or may not be used, but to set out a clearer picture of the key considerations. The Dynamic Coast data will be incorporated to identify areas of risk and it is hoped that community workshops in 2020 will provide a local response, which, along with a development of a monitoring plan, will inform the guidance.

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Adaptation and relocation of built heritage: what can we learn from the urban transformations of Swedish mining towns?

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Abstract

In the arctic and subarctic region, climate change may require in the future the relocation of entire communities, with dramatic impacts on their built heritage. In northernmost Sweden, the two arctic mining towns of Kiruna and Malmberget are already experiencing similar disruption due to subsidence caused by mining. This paper investigates the actions implemented to mitigate the impacts of the ongoing urban transformations. Historic buildings and entire districts are demolished, documented or relocated, sometimes with the ambition to recreate historic environments. These controversial processes exemplify the scale and the level of the challenges and dilemmas that climate change will soon pose to historic environments. Can relocation preserve the complexity of an historic urban environment? How are decisions on what to save made? How do the loss and the relocation of heritage affect the local communities? Discussing and understanding it is crucial to make northern historic sites and communities more resilient.

Keywords – Adaptation; Relocation; Built heritage; Urban transformations; Mining towns

1. Introduction

The arctic and subarctic areas are among the fastest changing regions in the planet and climate change is considered the most prominent driver of this [i]. Among the consequences of climate change that could have a potential dramatic impact on heritage sites and historic environments are sea-level rise, increased coastal erosion and permafrost thawing [ii]. The scale and impact of these changes may require in the future the relocation of entire towns and communities, including buildings and areas with cultural and historical value. In sub-arctic area of Sweden, the two mining towns of Kiruna and Malmberget are already experiencing similar disruption to their historic environments, due to landslides and subsidence caused by the ongoing mining activities [iii].

In 2004, Kiruna Council announced the need to move a significant part of the town in order to allow the state-owned mining company LKAB to continue its operations. Since the underground deposit of magnetite is located under the town, the subsidence caused by mining activities is affecting the historical core of Kiruna, funded in 1900, which is officially protected for its cultural significance. Malmberget, another mining town of cultural significance, is a similar but less known case. The town was founded in 1888 around a large iron ore open-pit mine but, as in Kiruna, magnetite is located under the town. Mining has caused problems for decades and the expansion of the pit has nowadays split the town in two parts. The agreements between LKAB and Gällivare Council of 2012 and 2016 have decided the fate of Malmberget: two thirds of the town will be lost by 2032. In both towns, the agreements include the relocation of a number of historic buildings in order to ensure the preservation of their cultural and historical value and of the memory of the towns. However, the majority of buildings composing these historic environments are just being documented and then demolished. In Malmberget the large-scale operation to relocate around 30 historic buildings from the company area to the near-by mining town of Koskullskulle started in 2016. In Kiruna, the moving of the historic buildings started in 2017 with some of the oldest and most important buildings from the company area moved to a new neighbourhood. In 2019 a new agreement to move 30 more historic buildings, partly to the new town centre, partly close to the new railway station, was announced.

Based on observations, literature and document studies, this paper investigates, describes and discusses the various and sometimes controversial actions that are being implemented to mitigate the impacts of the ongoing urban transformations on the built heritage of Kiruna and Malmberget. By presenting different cases from Kiruna and Malmberget, the next paragraphs will discuss the following questions: Who is in charge of the decision-making? How do we select what is important to save and what to let go? Can relocation preserve the complexity of an historic urban environment? How do the loss and the relocation of heritage affect the local communities?

2. Decision making and competing actors

A first controversial point relates to the decision-making process around the urban transformations in Kiruna and Malmberget. Decisions are usually the result of agreements, compromises and negotiations between LKAB and the local and regional institutions, including conservation authorities.

In Kiruna, the entire town is designated a heritage site of national interest. The conservation plan adopted in 1984 and the following detailed development plans had protected a large number of historic buildings. In addition, there were also a number of listed buildings, protected by the state, including the former Town Hall and Hjalmar Lundbohmsgården, which was the residence of LKAB's first manager. During the urban transformation a controversy developed regarding the built heritage. The main actors involved in this were on the one hand LKAB and Kiruna Council, and on the other the County Administrative Board of Norrbotten and, to some extent, the National Heritage Board. In 2009, a new detailed development plan covering the area closest to the mine was created. The purpose was to turn the land into a green area, to work as a buffer zone between the settlement and the industrial area. Initially, the local authority suggested that all of the previously protected buildings were to be relocated. However, this was altered in the plan adopted in 2011, which indicated that only five of the originally twenty-three protected buildings would be moved. During the time between the two versions of the detailed development plan, Kiruna Council and the mining company LKAB had made a civil law agreement, deciding which buildings to move. It was up to twenty-one buildings in total, including some of the workers housing from the company area, as well as Hjalmar Lundbohmsgården. According to the agreement, LKAB was also to build a new town hall, to replace the existing, listed one. This was not accepted by the County Administrative Board of Norrbotten, who argued that more buildings must be preserved through relocation in order to keep the integrity of the historic environment which is of national significance. After LKAB threatened to close the mine, it was agreed that two more buildings from the area would be preserved by relocation, and the Kiruna Council committed to finalise a baseline study of the historic environment [[iv]]. The selected buildings for this phase were moved in 2017. In 2019, it was announced that, based on discussions and negotiations between Kiruna Council, LKAB and the County Administrative Board, an additional thirty buildings were to be relocated during Kiruna's urban transformation. In Malmberget, similar negotiations have been taking place, resulting in a larger number of historic buildings being preserved there also. It must be remembered that, according to Swedish law, LKAB has to compensate for the impact mining activities have. On the one hand, this makes it easier to cover the costs for saving historic buildings. On the other hand this, together with the overwhelming influence of the company

in the economy of the towns, causes a power imbalance in the decision making.

Figures 1 and 2. A typical "Bläckhorn" house in Kiruna made in bricks before and after its demolition despite of its heritage value. Timber houses of the same typology were instead saved since the relocation was cheaper and easier.

3. Selecting what to save: HERITAGE value versus technical feasIbility and economic viability.

As described above, the assessment of heritage values, though sometimes not entirely agreed by each actor, is the basis for the selection of the buildings to be saved and relocated. But of course, this is not the only criterion considered in the decision making. The technical feasibility and economic viability play also a determinant role. It is not by chance that mostly timber buildings have been relocated up to now, both in Kiruna and Malmberget, one of the reasons being that the procedure is much easier and cheaper compared to moving masonry or concrete buildings. The costs of the operations are important in determining how many buildings will be moved. Lower cost means that more buildings can be moved and may also make the option of relocating preferable to demolishing and rebuilding. In Malmberget, the operation of moving a few modern villas as a test in 2007 to assess future possibilities proved to be complicated and expensive because the entire building was moved, including the concrete basement floor [v]. When the relocation started in 2016 it was decided that only the upper part of the buildings, which were mainly in timber apart from the masonry chimneys, would be moved. In just one case the basement was not substituted with a new crawling space, as its stonework was considered worthy of preservation and it was decided to cut out the external surfaces of the stones and use them as cladding.

In Kiruna the recognised outstanding cultural and symbolic value has allowed some buildings to be prioritised or to receive an extra-effort in order to save them, like in the already mentioned case of Hjalmar Lundbohmsgården. Another example is Kiruna church, which according to the plans should be moved in the next few years despite the complexity of the operation. This was not the case for the Town Hall by Artur von Schmalensee, inaugurated in 1963 and listed in 2001.The 2011 civil law agreement established that a new town hall was to be built by LKAB, signalling the intention to demolish Schmalensee's town hall. Kiruna Council and LKAB requested the protection of the building to be repealed. Given the building's significant heritage values, the County Administrative Board investigated in which way and to what extent it would be possible to dismantle and rebuild the Town Hall and how much this would cost. The request was rejected since it was found that it would be reasonable to partly dismantle and rebuild, and partially to reconstruct the building based on the original blueprints. This decision was appealed twice by Kiruna Council and LKAB until the Administrative Court of Appeal judged in favour of the Kiruna Council and the mining company [4]. The Town Hall was thus demolished in 2019, apart from the clock tower that used to stand on the top of the old building. Only minor details and some furniture have been integrated in the newly built town hall, as a symbol of the new Kiruna. According to some estimations at the end of the works, not only was building the new town hall far more expensive than anticipated, but even the cost of demolishing the old town hall exceeded the costs estimated by the County Administrative Board´s investigation into the dismantlement and rebuilding of Schmalensee's masterpiece.

4. How to recreate complexity?

The case of the relocation of around 30 buildings from the company area of Malmberget to Koskullskulle is quite interesting and shows that saving an entire building, even a coherent group of buildings, is much simpler than recreating the complex social interactions, historical stratification and cultural relationships that are created over time in a living urban environment. Looking at how the buildings were selected in the cultural heritage assessment [vi], it is evident that there had been an effort made to diversify the buildings to be preserved according to typology and age: workers' houses from the end of the 19th century (the "pioneers' phase") are relocated together with post-war modernist villas for the "white collar workers" of the company. Also the morphology of the old settlement is considered and in some cases, significant and homogenous groups of building were relocated keeping their disposition, as in the case of the sequence of four aligned jugendstil buildings known as Långa raden (the Long Row). The design of the new neighbourhood even tries to preserve where possible the spatial relationships between the buildings, their orientation and their connection to the landscape by trying to provide some of the building with a comparable view from the windows.

It is nevertheless interesting to note that most of the buildings that have been relocated from Malmberget to Koskullskulle are those of the company area of the town and especially those already owned and managed by LKAB. Despite the remarkable effort to recreate the variation, morphology and the hierarchy of the urban environment typical of company towns, the result will likely be that just a limited part of the complex identity of Malmberget before the relocation will survive. Furthermore, it looks like, both here and in Kiruna, the pattern of the company area as a separate part of the town will be recreated, reinforcing the role of LKAB as the predominant actor in the history of the two towns [3]. The risk of excluding other possible narratives is an important point to consider in the relocation of heritage sites.


Figures 3 and 4. Workers' houses from the company area of Malmberget relocated in Koskullskulle. The same houses reproduced in their original disposition by the artist T. Pettersson in his "Malmbergsmodellen".

5. Local communities between social acceptance, nostalgia and criticism

A discussion of the response to the urban transformations of Kiruna and Malmberget is very controversial and exceeds the scope of this paper. The case of Kiruna, in particular, has achieved an international profile and on the one hand it is mentioned as a successful case of resilience in the 2016 Arctic Resilience Report [vii], but, on the other hand, Nilsson has discussed how the whole process was biased by a strong "ideological phantasy" created by LKAB and Kiruna Council to claim public support for the relocation of the town [viii]. It is generally assumed that the largest part of the population of the two towns agreed with or accepted quite passively the urban transformations. Some initiatives promoted by local groups and associations can nevertheless be quoted as examples of how diversified the reactions of the communities of Kiruna and Malmberget were to the loss of their built heritage.

The local interest group Kirunas Rötter (Kiruna Roots) has been quite active in taking a stand on the historic environment of the town. During the planning process for the new town plan, the association developed and presented its own vision for the relocation of the historic buildings, which envisioned a cultural neighbourhood including several historic buildings together with newly built cultural facilities [ix]. The same association promoted an initiative to invite citizens to share their thoughts and feelings about the relocation [x] and contested the outcome of the agreement between Kiruna Council and LKAB calling for more inclusion of the citizens in the discussion on the future of built heritage [xi].

In Malmberget, a remarkable initiative was "Farväl Focus" (Farewell Focus), promoted in 2019 by Pernilla Fagerlönn and several local associations. It was a one-week festival organised within the emptied and soon-to-be-demolished Focushuset, a 13-storey apartment block that was the symbol of the 1960s development in the disappearing town [[xii]]. The festival gathered artists, locals and former inhabitants in a sort of common mourning for sharing thoughts and feelings about losing a piece of their personal and collective history. A similar feeling of nostalgia is at the basis of the Malmbergsmodellen initiative, within the project "Dokumentera Malmberget". The local artists Tord Pettersson and Jan Åkerlund have collected their own and the local collective memories by reproducing the whole town in an impressive reversible model showing how Malmberget looked like before and after the urban transformations of the 1960s.

6. Discussion: what can we learn?

Different problematic aspects regarding the relocation of two Swedish mining towns with cultural value were presented in the previous paragraphs. There are in our opinion many similarities with the situation that many heritage sites may have to face in the next future due to climate change, especially in the North.

First of all, the cases of Kiruna and Malmberget show that many conflicting social, economic and cultural interests are at stake in such a complex process as the relocation of historic towns or large cultural sites. In our cases, the presence of such a strong actor as the mining company biased the power relations between different actors and stakeholders. The decision making could have sometimes been managed in a more transparent and inclusive way, involving more actively the communities and the local associations in the discussion. This is surely something that those that will be in charge of taking similar decision for sites in danger will have to consider.

As we have shown, even when the physicality of the built environment can be moved and somehow preserved or replicated, the intangible values of the site will be most likely compromised. The selection of the most valuable parts of a site, when needed, will inevitably simplify its significance by excluding other narratives or by erasing alternative meanings. The presence of indigenous cultures, which is common in many parts of the Arctic, will likely exacerbate this issue and will make the need for a more inclusive decision process even more urgent.

In the cases presented, the fact that the mining company had to compensate for the impacts of its operations made a considerable amount of financial resources available even for complicated and expensive operations for saving the cultural heritage of the towns. It is not something that we can expect in the moving of a heritage site due to climate change impacts, where it is likely that governments or public institutions will have to fund the rescue operations of heritage sites. This makes the decision on how to use the allowable funding even more problematic and difficult. As it was shown, there is a risk that budget estimations and technical feasibility reports may be prioritised over the heritage value in decision making. Unfortunately, these numbers can be biased, unreliable and subjective, especially when dealing with complex operations on historic buildings. Careful assessments, including qualitative and quantitative methods, as well as openness and flexibility in considering alternative options are vital in preventing unnecessary loss of heritage.

7. Conclusions

The paper has presented several aspects from the urban transformation of the historic mining towns of Kiruna and Malmberget, in northern Sweden, where an extensive relocation of historic buildings has taken place together with controversial decisions causing the loss of important elements of the local heritage. We claim that the scale and the level of the challenges and dilemmas that these processes are posing to these two Swedish towns may exemplify very well those that climate change will pose to the conservation and management of other arctic or subarctic historic built environments in the near future.

In our opinion, it is almost impossible to establish whether what has been done is enough. If many decisions can appear questionable or insufficient from a conservation perspective, the tremendous effort and investment of resources that has taken place must also be recognised, an investment that may not be so easily replicated in other situations. We think that it is important to present these cases, to discuss them and to try to understand both the complex processes behind them and what could be improved in terms of community participation and inclusion in the decision making around the adaptation of built heritage [[xiii]]. Having the possibility to learn from these experiences may be crucial in the future to make northern historic sites and communities more resilient to climate change.

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Virtual Reality, Museums and engagement with sites at risk

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Abstract

Virtual reality offers ways of engaging with cultural and natural heritage which contributes to preservation by promoting appreciation of the sites. This paper discusses a virtual museum infrastructure which makes it easy for museums and for other heritage organisations to create virtual reality exhibits and exhibitions of sites that are at risk through climate change, conflict and pandemics. Virtual reality can both enhance an onsite visit and enable visitors to engage remotely, whether it be through virtual reality apps, the web or social media. A Virtual Reality exhibit may provide remote access to a site as it is (in recorded or live form) and may also provide access to an interpretation of a site, presenting it as it may have been in the past or maybe in the future. This paper discusses a digital infrastructure which makes it easy to create virtual reality exhibits and exhibitions of sites that are at risk. At the time of writing 93% of museums in the world are closed, physical access to heritage is all but impossible and audiences unable to travel to heritage sites. At the same time there is an appetite for digital engagement with heritage through social media, the web, and traditional media. Newspapers feature lists of virtual tours and prominent engagement. We also discuss how the a VMI has enabled remote access to sites within the context of lockdown. Through examples from the CINE and EULAC project we show how Live! Events and Virtual Museums focus and drive engagement with heritage.

Keywords – Climate Change, Archaeology, Virtual Reality, Live Virtual Tour, COVID 19, #museumfromhome

1. Introduction

This paper provides an outline of a Virtual Museum Infrastructure developed by the CINE project and how this enables the development of Virtual Reality exhibits and exhibitions for sites that are at risk from climate change and other threats. The role of digital in preserving and promoting heritage has been becoming more important over the last decade. Virtual reality, augmented reality, interactive mapping and digitisation have all been contributing to new ways of engaging with heritage. Climate change has been impacting upon our heritage, putting at risk coastal sites and increasing risks associated with extreme weather. Taken together with damage to heritage from conflict and events such as the fires at Notre Dame, the National Museum of Brazil and Glasgow School of Art the safety of our heritage cannot be taken for granted. This has motivated interest both the digital preservation and promotion of heritage. The increasing computational and graphical capability of computers and mobiles underpin the mass availability virtual reality, and the widespread digital literacies. Consequently, is a practical proposition for enhancing engagement with sites at risk. The impact of COVID-19 on the heritage sector has been huge. Lockdown prevents visits to museums and historic sites. For now, at least engagement with heritage is often only practical through digital means. In the last few weeks we have seen museum professionals and volunteers taking to their key boards, with social media posts, seminars, virtual tours and other forms of interaction. These have been met with enthusiasm by an online public reflected in online statistics such as growing view numbers, page likes and positive feedback.

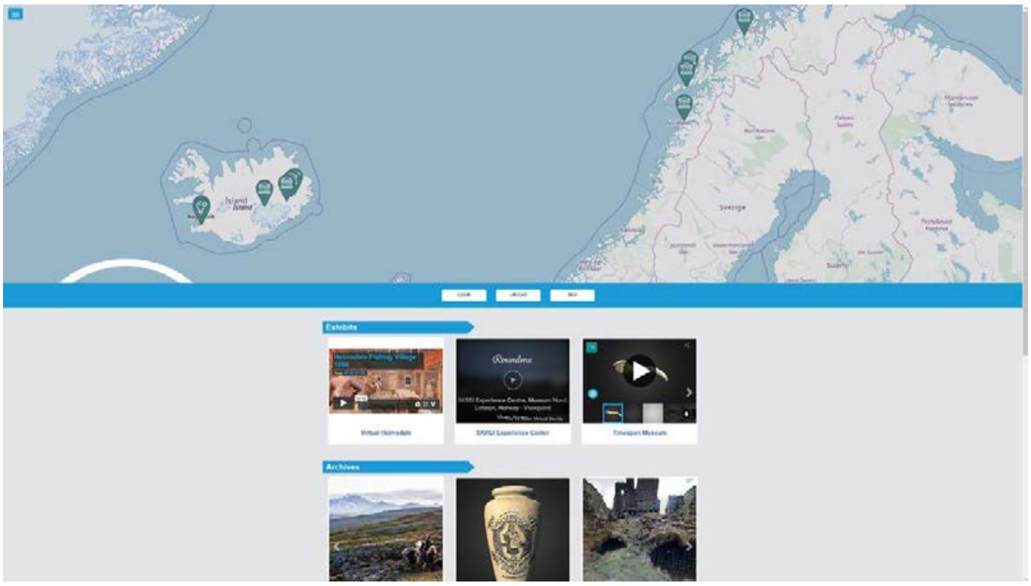

Figure 1. Front page of the CINE Virtual Museum, www.cing.org

2. Virtual museum infrastructure

The CINE project set out to address digital support for the promotion and preservation of heritage.

"Museums are perceived as centralised institutions based on specific collections within specific buildings. Connected Culture and Natural Heritage in the Northern Environment (CINE) embraces the concept of Museum Without Walls - an outward facing museum that takes an active role in challenging perceptions, in fostering social change and in providing access and information to diverse audiences, using new technologies to step beyond the traditional museum context."

There are many ways to represent a site at risk. These include using spherical media to create virtual reality tours. The tours may have hot spots which bring up 3D representations of objects from the site. CINE proposed the design of **"**A Virtual Museum Infrastructure" that provides easy to use interfaces which enable community engagement in the creation, curation and management of digital virtual reality exhibits and exhibitions. It integrates the treatment of spherical, 3D and other audio-visual data enabling the creation of virtual and mixed reality exhibitions. It enables data to be curated and reused within multiple use cases and supports the creation of location aware applications. It also supports live virtual tours and smart tourism. In realising these objectives, we addressed the following issues:

1) The creation and capture of digital scenes, artefacts and narratives.
2) The archiving of data and associated meta data within digital repositories
3) The augmentation of physical exhibits and the creation of virtual exhibits.
4) Support for the intuitive curation of exhibitions by domain experts.

The system has been engineered to ensure user quality of experience. It includes toolkits and helps organise training to support creation of digital objects, spherical media and digital reconstructions.

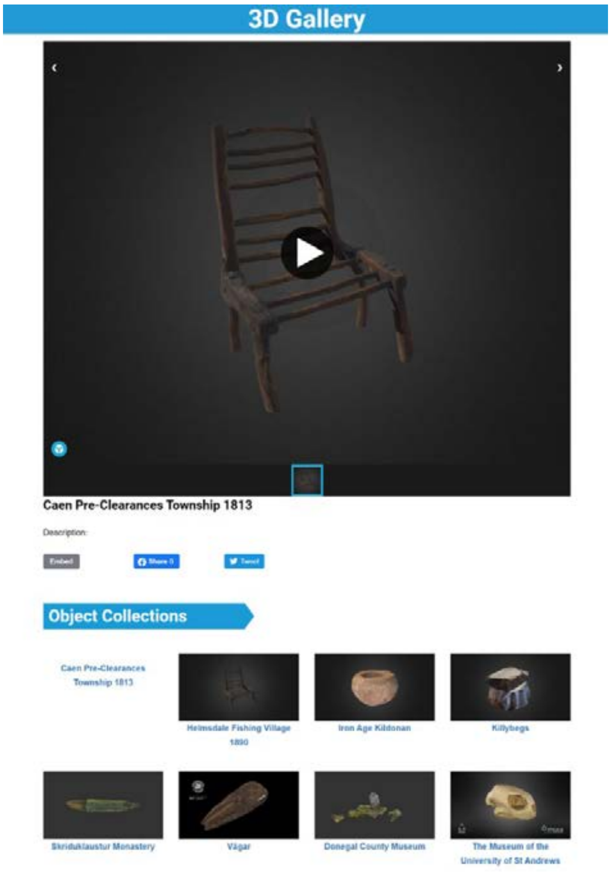

Figure 2 Digital Galleries of Artefacts

We have developed an application profile to define metadata and provide a clear ingestion mechanism through form upload. The data archive system *associates* source materials with items, e.g. a spherical image will be associated with its source images. The VMWW uses OMEKA which extended to support the creation of mobile apps, web exhibitions, museum installations, virtual and cross reality apps as well as map, social media and wiki interface. The virtual museum was first developed as part of the EULAC Museums project[1] [1] and the Northern Peripheries and Arctic Program CINE project [2] will be the template used in supporting this endeavour. An Exhibition section provides access to exhibits and exhibitions and other directly curated content.

1) Museums and Gallery section provides access to galleries of digital content. The galleries contain virtual tours of sites both as they are now and of how they were in the past as well as collections of digital artefacts.
2) An archive section enables the upload of media, and metadata, as well supplying search and update features.
3) Toolkits provide user guides, best practice documents and online resource that help in creating digital exhibits and exhibitions.

[1] EU-LAC-MUSEUMS: Museums and Community: Concepts, Experiences, and Sustainability in Europe, Latin American and the Caribbean. This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 693669

Figure 3 Museums using the EU LAC Virtual Museum, museums have virtual tours and virtual galleries https://eu-lac.org/galleries/museums.php

Interactive map and map making resources connect with items in the archive. The system also provides connectivity with social media and other collections. If resources are hosted elsewhere a link to them can be upload rather than the resources themselves. Connect with social media mean enables digital resources in the VM to be used on Facebook pages, groups and timeline, to be tweeted or embedded in emails, web pages etc.

3. Modes of virtual reality engagement with sites

Remote access to heritage sites offers advantages for sites at risk. It enables audiences to be engaged by the heritage without visiting the site. This is particularly valuable where encouraging visit to the site is likely to cause erosion or to damage the site in other ways. In the context of COVID-19 lockdown and aftermath remote access that virtual reality offers will be a key way of engaging with sites at risk [3]. The site of a Medieval Monastery in Skriduklauster provides a good example of how virtual reality technology can be used to provide access to and engagement with sites at risk from climate change. Digital advances are transforming the way people engage with heritage. Virtual Reality (VR) headsets offered the possibility of immersion to historical times and places inaccessible due to barriers of space and time. Digitisation through photogrammetry and scanning enabled the creation of virtual galleries of 3D digital artefacts [4]. Spherical media supports the creation of engaging scenes that captivate the visitor in natural and cultural heritage [5].

Figure 4 Digital reconstruction of Skriduklauster monastery site accessible via Roundme, Facebook, Google Maps, VR App Museum Exhibit and Live Streaming.

Widespread digital literacies had enabled VR exhibits in museums and galleries prior to their closure. The capabilities of commodity computers, cameras, mobile phones and drones made it possible for digital media, interactive exhibits as well as digital or mixed media exhibitions to become a normalised part of the workflows of heritage professionals and volunteers [7]. Virtual reality was progressively changing from a method of engagement only produced for high-end exhibitions created by specialist companies, to integrating within the processes of exhibition development and produced by project partner, students or adept museum staff. There is widespread access to the internet through smart phones and broadband which enables access to virtual museum content [8]. There are multiple ways in which VR can be used with sites at risk. A virtual reality exhibit can provide an immersive onsite experience. A VR headset connected to a computer with a powerful graphics card offers the potential of an immersive high-quality experience. Delivery of virtual reality through an app offers the possibility of a mobile cross reality experience. However, both of these methods require physical presence at the site. Virtual Reality can also be used for remote access to a site. Thus, a digital reconstruction can be downloaded and played as a game at home. Spherical media can be organised into a tour, augmented with commentary and engaged via the web, a mobile app can provide a remote VR experience or live streaming can be used to combine these approaches.

4. Examples of remotely engaging with sites and audiences

In this section we discuss two examples of remote engagement, a Live video conference with Facebook streaming of the Skriduklauster Monastery and a Virtual Museum exhibit focussed on the Empire Windrush. The current circumstance of lockdown COVID-19 means restrictions on travel make remote engagement techniques more important. This is likely to remain the case for some time to come. Even

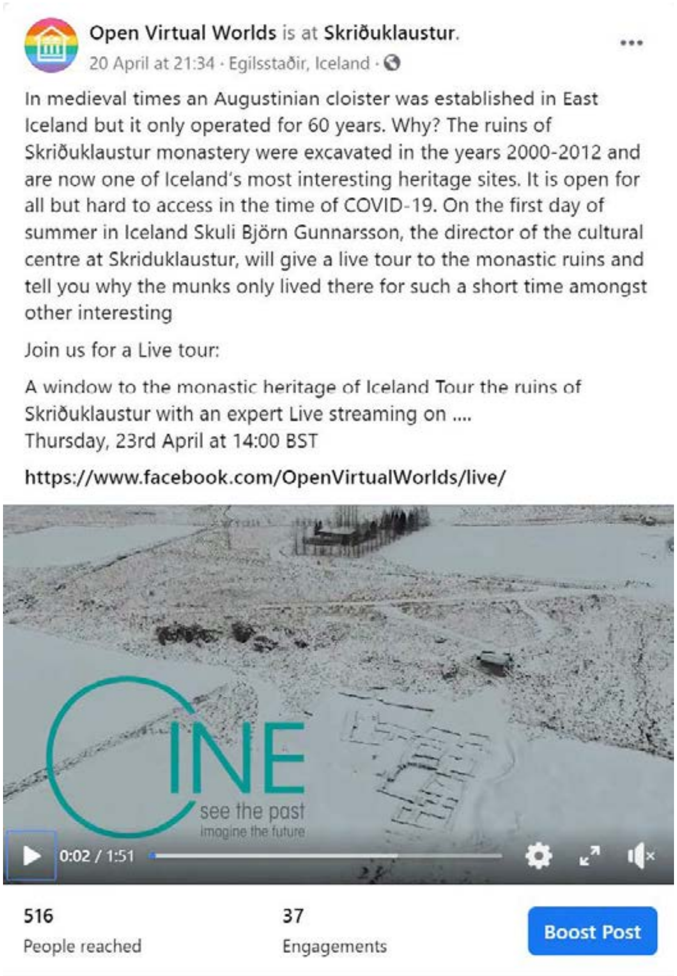

Figure 4 Facebook Live tour of Skriduklauster Iceland
https://www.facebook.com/323287317757618/videos/570167030549900

when restrictions are lifted remote engagement will remain important. The VMI infrastructure simplifies the process for museums and other heritage organisations to reach out to audiences in the home, by providing services, digital toolkits, exhibition building resources and delivery frameworks [9]. Each type of heritage has a metadata form which supports the creation of metadata based upon the Dublin Core standards [10]. Much can be achieved with equipment already in the home, web cams and mobile phones can be used to create virtual tours and to broadcast live streams. Toolkits provide support for the creation of digital content using equipment that is likely to be readily available even to small museums.

The Skriduklauster event contained several elements. There was a live tour of the archaeological site with commentary. There was also a tour of the site as it would have been in the 16th Century. There was also a gallery of 3D artefacts which were excavated from the site. The fourth element was a question and answer session about the site. Figure 5 shows the Facebook advert for the event. It brought together archaeologists, historians and museum experts in discussing Skriduklauster monastery in the East of Iceland. The event consisted of two elements a Zoom conference and it was broadcast as a Facebook Live! Event. Around 20 people participated in the video conference – the panel and a class of master's students. For example, Figure 5 shows the advert for an event on Facebook, which brought together archaeologists, historians and museum experts in discussing Skriduklauster monastery in the East of Iceland. The event included a live guided tour of the site, exploration of a digital reconstruction of the site as well as discussion and questions from the panel. It consisted of two elements a Zoom conference with panel and audience and was broadcast as a Facebook Live! Event. Over 4000 people interacted with the Facebook event before, during and after. During the event they were able to contribute to the chat and to ask questions by text. Those in the video conference stayed for the whole session, which lasted an hour, and were able to ask questions verbally.

A second example is the Virtual Museum of Caribbean Migration and Memory. This can be accessed as a web resource and contains interactive panels and an interactive map showing sites of origin and destination. These are combined with 3D models and recordings of performance [11] as well as stories of migration. It forms part of the Barbados Museum and Historical Society #museumathome program and illustrates how.

To complement the virtual museum and toolkits and as part of the CUPIDO project we are developing workshops accessible via Zoom. The program will include topics such as: Creating Media Developing, Publishing online, Curating exhibits and Live engagement. The combination of synchronous and asynchronous communication also enables online courses which build the capacity of heritage professionals at home.

5. Conclusion

The motivation for the digital representation of heritage has in part come from a desire to address the threats of climate change, conflict. These have been empowered by advances in technology underpinning immersive and mobile engagement with heritage. These have motivated the idea of a Virtual Museum Infrastructure which enables museums in working with digital content. The impact of COVID-19 on the heritage sector has been catastrophic, but there has also been a positive response with museums instigating virtual tours and engaging through social media. This motivates the idea of refocussing and refactoring the Virtual Museum Infrastructure to enhance support for working with heritage from home and publishing heritage to people's homes. Much of the VMI is useful in this changed context as the digital archiving system enables the creation of exhibits including interactive maps, virtual tours, galleries and apps. It connects with social media, social archive and maps providing support deployment of media. The system is accessible from the home both for content creation and for access exhibits and exhibitions (https://link.springer.com/chapter/10.1007%2F978-3-030-23089-0_8).

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Dunbeg Promontory Fort and Medieval Settlement site, Co. Kerry: the archaeological management of retreat and loss.

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Abstract

Dunbeg (Dún Beag) Fort in Dingle, Co. Kerry has been subject to impact and loss over the centuries, but the intensity and frequency of storm events and proliferation in precipitation in recent years has significantly increased the vulnerability of the site. Extensive collapse on its seaward edge in 2014 and again in 2017, in conjunction with considerable impact from floodwaters, caused major loss and damage. The National Monuments Service (NMS) of the Department of Culture, Heritage and the Gaeltacht, in collaboration with our colleagues in the Office of Public Works (OPW), has implemented an archaeological mitigation strategy to address the most recent impacts. Integrating targeted archaeological survey, excavation and recording, supported by results from associated surveys, the strategy informed the management of retreat and loss at the fortified site. A monitoring brief is in place to assess any further impacts following weather events and enable a continued cultural heritage and conservation rapid response, while also facilitating community engagement through continued, albeit restricted, access to the national monument.

Keywords –increased vulnerability; collapse, archaeological strategy; rapid response; monitoring brief.

1. Dunbeg (Dún Beag) Promontory Fort and Medieval Settlement Site

1.1 Cultural Heritage Overview

Dunbeg, or as its name in Gaelic suggests – 'Dún Beag', or 'Little fort' – is a fortified site located at the coastal edge of the Dingle Peninsula, in the townland of Fahan. The site is a National Monument in the care of the Minister for Culture, Heritage and the Gaeltacht, and is managed by the Office of Public Works (OPW), who undertakes the conservation work at the site, under Ministerial Consent. Dunbeg is a fine example of a prehistoric promontory fort and medieval habitation site and remains one of the most popular sites to visit along the Slea Head Drive. It is one of 350 such promontory forts known from around the coast of Ireland and is representative of some 510 recorded monuments in the immediate Dingle hinterland, the majority of which date to the medieval period. Construction of Dunbeg probably began in the Iron Age, over 2500 years ago, with the site occupied periodically until the 11th century AD.

The site consists of four outer defensive banks of stone and earth that were far more extensive when the site was occupied, but much of their western extent has been lost to the sea through time. In the interior a stone-built rampart provided protection to a single circular hut site or clochaun (clochán), which is located at the southernmost edge of the monument overlooking the sea. A flag-covered souterrain or underground passage runs from the innermost earthen defensive bank, beneath the rampart and leads to the clochaun. Other features include a defined pathway through the site flanked by upright stone flags and, prior to the 2017 collapse, an iconic lintelled entranceway with two side chambers was located within the western extent of the inner stone rampart.

Figure 5. Aerial oblique view from southeast of Dunbeg Fort in the 1980s (© Walter Horn, courtesy of OPW)

1.2 Climate Impact, Collapse and Flood Damage

In February of 2014 Storm Darwin (Cyclone Tini) caused the western perimeter of the fort – a section of the cliff face measuring approximately 100m – to collapse into the sea, including part of the stone rampart and enclosing defensive banks and ditches. A safety fence along the western boundary was erected by the OPW that enabled continued access to the site by visitors. In November and December 2017, however, following two successive severe storms accompanied by intensive precipitation, the site suffered further catastrophic collapse on its western edge along with extensive damage internally from the ingress of flood waters coming off the slopes of Mount Eagle to the north of the monument [1]. The flood waters scoured out deep fissures and deposited large quantities of gravels and stones into the site, spread from the visitor's entrance to the rampart wall. The iconic lintelled entranceway and its chambers in the stone rampart was also lost during the December 2017 collapse, with only one lintel remaining, which was rescued and is now on display at the site. In the intervening three years between 2014 and 2017, due primarily to intensification of precipitation, visitor footfall impact at the monument was also identified as a concern. Abrasion leading to erosion due to the sodden nature of the ground was occurring to specific areas in the site, including the earthen defensive banks, and this led to conservation work previously carried out being undermined.

Such was the nature of the impact in 2017, however, that the site had to be closed to visitors, and remained so for two years pending appraisal of site stability, vulnerability and safety. Integral to discussions between NMS and OPW was the implementation of an adaptive management and conservation strategy that addressed current as well as future intensified climatic impacts. The strategy included targeted archaeological mitigation funded by OPW [1].

Figure 6. Flood damage at the site in 2017, with scoured areas and deposited heavy gravels (© NMS)

1.3 Archaeological Mitigation History at The Site

The NMS have been aware for some time of the site's vulnerability to coastal erosion, with an archive of material tracing impacts over the decades [2]. This has allowed for planned archaeological excavation ahead of potential loss and in the late 1970s extensive archaeological excavation was carried out by NMS at Dunbeg Fort. Three quarters of the site was archaeologically investigated at the time and revealed evidence of man-made construction dating from 580BC (a date from the lowest levels beneath the stone rampart), to the medieval period, with the excavation of the clochaun revealing evidence for occupation up to 1000AD [3].

Figure 3. Excavation at the clochaun in 1977 with external drain and souterrain revealed (© NMS)

In 2014 archaeological monitoring was carried out during the erection of the western boundary fence following Storm Darwin damage. Evidence for a possible iron knife blade or chisel was recovered at that time. In 2015, to address visitor footfall impact, archaeological monitoring again assisted the OPW's conservation works. In 2018 and 2019, following agreement on the logistics for visitor access, and which required an internal fence and new pathway, further archaeological excavation and monitoring was necessary, particularly as sections of the access path were routed through areas not previously archaeological investigated. The most extensive area excavated was Cutting 1, through Fosse 1 & 2 and the intervening Bank 1 on the southeast side of the fort, with preliminary results potentially identifying evidence for an earlier bank beneath the stone rampart and which may tie in with the Iron Age date from recovered from that area during the archaeological excavations by NMS in 1977 [1 & 3].

2. Management and Conservation Strategies

2.1 Methodologies Adapted

The National Monuments Service and OPW explored all options for the long-term future of the site. These options were informed by expertise engaged by OPW: they included consultant engineers who carried out an assessment of the safe access options at the site [4] and a geophysical survey to assess the sub-soil conditions, sub-surface geological layers and depth to bedrock across the site [5]. Both assisted with projections of stability, identifying fault lines across the site and with agreeing the location for the pathway and internal fence to facilitate on-going public access. The archaeological strategy was, in turn, influenced by the location of the pathway and fence through previously unexcavated areas as well as the recognition that the archaeological investigation may add further valuable information to our understanding of the cultural significance of the site in advance of unavoidable loss. High resolution drone and LiDaR surveys undertaken by the Discovery Programme as part of their CHERISH Project similarly added essential additional data to the cultural veracity of the site [6].

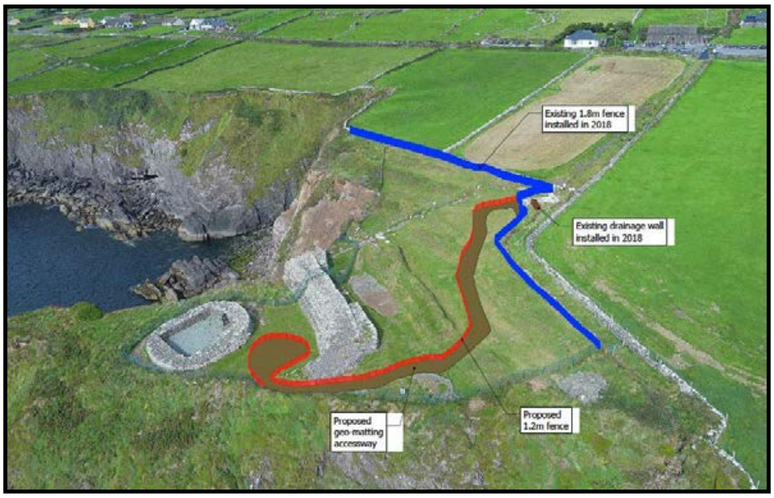

Figure 4. Agreed route, in red, of internal fence and pathway allowing continued visitor access to site after 2017 damage; blue line indicated additional northern perimeter fencing (© OPW)

2.2 Results

The options were further informed by community engagement, particularly with the adjacent landowners who run the local visitor’s centre and own the approach pathway that leads down to the entrance to the national monument. Their wish to have access maintained, along with the wider economic tourist value to the region, were key considerations in the adaptation of methodologies implemented at the site. The site reopened in the summer of 2019 and visitors can continue to enjoy this important national monument. New interpretation is planned at the site early in 2020 to provide visitors with information on the cultural significance of the site, the conservation works carried out and the climate impacts that have led to loss over time.

Further collapse at the coastal cliff edge site of Dunbeg Fort is inevitable as storms and rainfall continues to intensify. A monitoring brief is in place at the site subsequent to such weather events to assess impact, safety and access. The management and conservation strategy adapted for Dunbeg Fort, which was a multi-disciplinary approach, is informing management and conservation considerations at other sites across the southwest coast that are also being affected by on-going climate change impacts. Dunbeg is a key case study in our recently published *Built and Archaeological Heritage Climate Change Sectoral Adaption Plan* (2019) and ongoing monitoring and assessment of the condition of this significant archaeological monument will continue to inform the implementation of that plan [7].

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Session 9: Urban Assessment

Session chair

Tor Broström, Uppsala University, Sweden

Presentations

Specification of the planning process of adaptation urban areas with historic objects to climate change

Eva Streberová, Chief Architect's Office, Slovak Republic

HYPERION – A decision support system for improved resilience and sustainable reconstruction of historic areas

Antonis Kalis, I-SENSE Group, Greece

Data-driven and community-based resilience improvemnet of historic areas: SHELTER project

Aitziber Egusquiza, Tecnalia, Spain

Specification of Planning Process of Adaptation to Climate Change in Urban Areas with Historic Objects

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Abstract

The quality of city life and well-being of city dwellers are a main goal of urban planning approaches. Unsystematic planning approaches of cities and the absence of relevant information can be a trigger that deteriorates the ecological sustainability of a city. This contribution focuses on how an increasing trend of co-creation between experts from different fields acts as a stimulus also for involvement of a broader spectrum of stakeholders and self-government into the process of spatial planning system in Slovakia.

The complex interrelationship enabling and disabling factors for the development of new planning systems as well as the utilization of databases, GIS tools, the cooperation with universities and other scientific institutions, and the application of new methodical approaches on risk and threat assessments are fundamental aspects of modern spatial planning. Using the example of the city of Bratislava, we demonstrate the incorporation of predicting threats and risks to historical areas caused by climate change into the spatial planning scheme.

Keywords: planning process; climate change; historic areas; city.

1. Introduction

In most European countries, a spatial planning process is subject to standard procedures, which consist of several stages or phases. The process starts with a preparatory phase, assignments (goal and purpose of the documentation), continues with data collection and preparation, and develops various types of documentation (land-use plans, territorial development studies, action plans, etc.). Throughout the stages, usually determined by binding methodological procedures, various stakeholders can participate in the process via reviews or statements (comments) on the materials and documents provided. Decision-making processes are carried out and finally the planning documents adopted by local self-governments and implemented. Part of the preparation of such documentation is also the process of strategic environmental assessment, which aims to predict threats and impacts the plans might impose on the environment and the health of the population [8]. Once a plan is adopted, cities – as bodies of self-government – have strategic documents at their disposal, which represent key materials for their own territorial development.

Spatial planning is a dynamic process responding to current stimuli and practical needs. The inclusion of the impacts of climate change as well as new associations of various other stressors and indicators of development need to be considered in the process of developing strategic documents. This is an example of the complexity of the whole planning process, in which the cooperation of many stakeholders is key. Demonstration of good cooperation between the fields of disaster risk management, cultural heritage and climate change is the European project funded by the European Union's Horizon 2020 research and innovation programme (GA no. 820999) "ARCH – Advancing Resilience of historic areas against Climate-related and other Hazards", which started in June 2019 and will continue until May 2022. Aim of this project is to develop a unified disaster risk management framework for assessing and improving the resilience of historic areas to climate change and natural hazards. Tools and methodologies will be designed for local authorities and practitioners, the urban population, and national and international expert communities. The project will present various models, methods, tools and datasets to support decision-making. The project consortium includes 15 partners, four of them pilot cities: Bratislava (Slovakia), Camerino (Italy), Hamburg (Germany) and Valencia (Spain).

2. New approaches in urban planning processes

The urban planning process is characteristic for a cooperation of experts from various professions and backgrounds. The effort to find solutions for land use in accordance with many rules and limits is often significant. In connection with the impacts of climate change, critical infrastructure, the impacts of extreme weather events, and measures to mitigate the impacts in terms of the comfort of urban dwellers are addressed as standard. Cities, besides being centres of economic activity, have a high concentration of historical monuments and other cultural heritage (tangible and intangible). Because of its crucial importance for society as well as its high vulnerability to climate-related hazards, cultural heritage is one of the key components that need to be considered in the sustainable development debate. Cities need to prepare themselves for the intensifying impacts of climate-related hazards and take protection of cultural heritage under these conditions into account. But in current planning process existing measures against climate change do not fully account for the specific conditions of heritage areas in Slovakia. Risks and vulnerabilities from climate change and other hazards need to be considered in the disaster risk management measures and policies for protection of cultural heritage explicitly. There are very few standardised tools in European countries for this specific area as well. There is an absence of relevant legal tools for enforcing adaptation measures by local authorities and self-government (cities, regions), absence of tools for assessing and improving the resilience of historic areas with regard to local climate change impacts, urban development strategies, spatial planning, adaptation and mitigation goals, etc. The ARCH project is targeting all these gaps, in order to help local authorities and self-governmental authorities to increase the resilience of their cultural heritage, and if possible, with this increase their overall resilience as well.

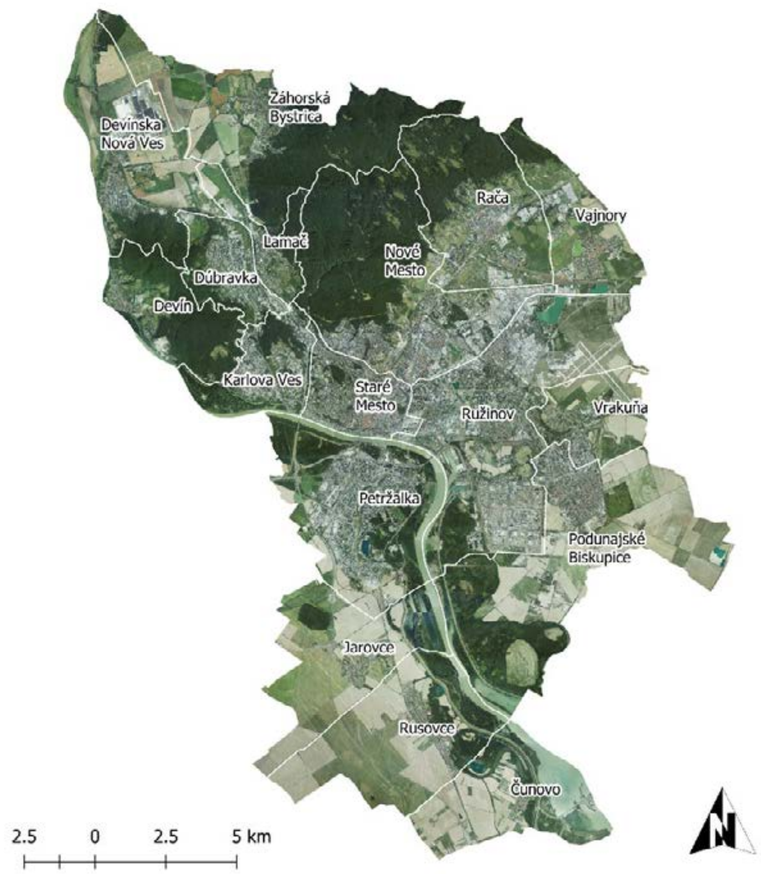
To reach this goal, the ARCH project uses co-creation as means of cooperation. Co-creation is a democratically governed creation and joint development of knowledge, models, methods, tools, services, policies, and strategies by the project partners and their stakeholders based on trust, transparency and effective communication. The co-creation process in ARCH takes an adaptive approach that responds to changing realities and endeavours to transfer results to local governments. For Bratislava, one of the city cases, the results of ARCH will be used to work out a comprehensive disaster risk management process for cultural and natural heritage sites, taking into consideration multiple hazards to which they are exposed as a result of climate change.

The support tools developed in ARCH project will be bundled in the ARCH Hub – a single information and data platform. The support tools will include:

- two information systems for geo-referenced properties of historic areas (descriptive, structural, architectural, material, and environmental hazard parameters); which transfer structured data into the ARCH Decision support system (DSS),
- the ARCH DSS - produces hazard models for impact scenarios and vulnerability analyses,
- a resilience options inventory to support identification of feasible resilience measures, linked to suitable funding opportunities,
- a resilience pathway visualisation tool to support graphical design of resilience plans,
- a resilience assessment dashboard for resilience self-assessment and formulation of resilience action plans.

3. Bratislava – case study

Bratislava is the capital city of the Slovak Republic, the political, economic and cultural centre of the country. The city is situated in central Europe bordered by Austria and Hungary on both sides of the Danube River, the second-longest European river. Bratislava has a total area of 367.9 km². Administratively, Bratislava is divided into five districts (state local government). For self-governance purposes, the city is divided into 17 City Boroughs [1]. The built-up areas of Bratislava are formed by three fundamental kinds of surface: continuously build-up historical areas serving chiefly for housing and services; looser housing, industrial, transportation, and recreational areas; and finally, large residential areas from the socialist period, usually designed as dormitories, on the city fringes. The whole territory of Bratislava comprises many areas with non-urban function, for example, agricultural land, forests, and water [3] (Fig 1).



Source: ZBGIS®, Geodesy, Cartography and Cadastre Authority of Slovak Republic (2018)

Figure 1. Bratislava City – divided by administrative borders into 17 city boroughs (municipalities with self-government).

3.1 Study sites

Bratislava's historical centre is situated within the former city walls in the Old town city borough. From the historical point of view the area is divided into a central historical monument zone and monument reservation (the medieval core of Bratislava) (Fig. 2).

The monument preservation zone is further divided into smaller areas called sectors, based on the character of built-up area, architecture, terrain and landscape. The monument reserve contains many historical buildings, fountains, historical gardens as well as other elements of tangible cultural heritage. Inside buildings as well as below ground level the area contains preserved heritage *in situ* such as the Celto-roman structures (masonry and floors) at Bratislava Castle hill [6], Celtic kiln and mint, which belonged to the manufacturing workshops in the Celtic oppidum that once spread across the centre of today´s Bratislava, remains of the city´s medieval fortification, St. James chapel [7] and charnel house and the Fisherman´s Gate [5]. These monuments as well as other (not yet examined) underground monuments are vulnerable to changes, for example surrounding surface permeability, intensive precipitation and rising groundwater levels, erosion and weathering, which are driven by climate change and urban development in the surrounding areas. Most of these monuments are under protection of the Bratislava City Museum and City Gallery and have the highest degree of monumental protection according to the Act no. 49/2002 Coll. of the national Council of the Slovak Republic on the Protection of Monuments and Historic Sites reflecting later amendments. Research on these sites was undertaken by the Bratislava Municipal Monument Preservation Institute, which is also partner in the ARCH project.

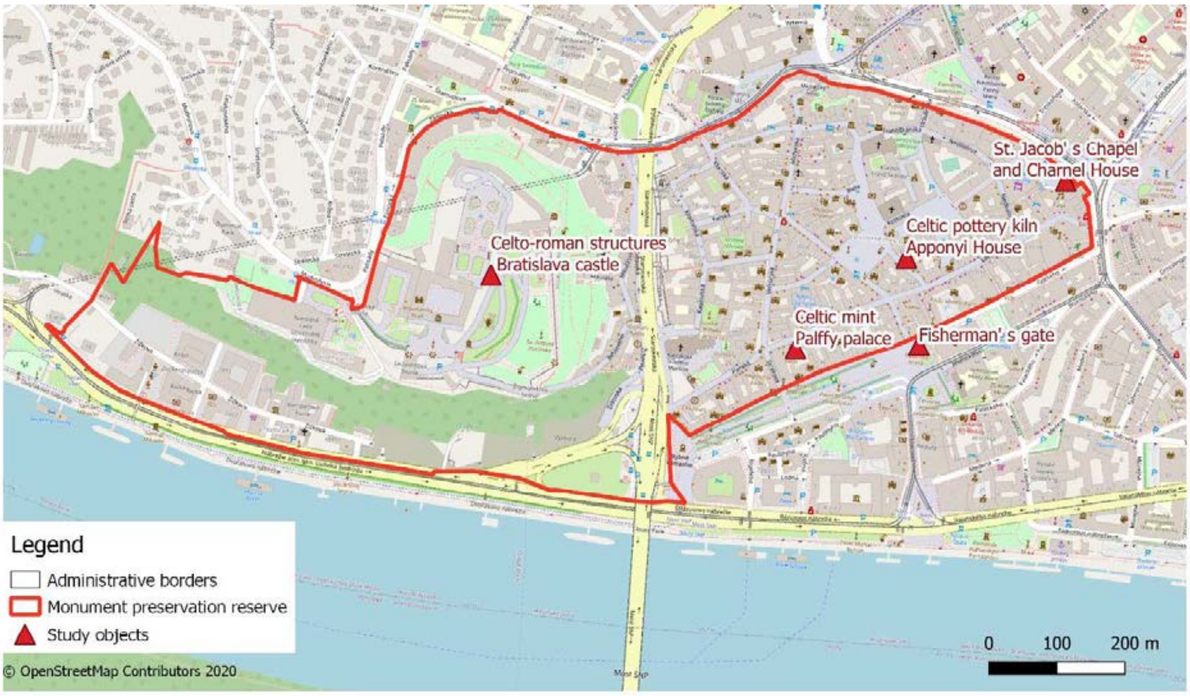


Figure 2. The significant historical monuments in the preservation reserve in Bratislava.

The Devín city borough is situated in the western part of the cadastral territory of Bratislava City at the confluence of the rivers Morava and Danube. It is well known for the Devín Castle national monument, the ruins of which are one of the most visited monuments in Bratislava (Fig. 3). Despite of its small size, the Devín Castle Hill is surprisingly rich in rock variety and geological history dating back to the Early Paleozoic to Late Tertiary period. Twelve open fissures with narrow karst and pseudo-karst caves (16 – 13 million years old) are beneath the castle in the rock cliff, where a permanent exhibition of finds such as ceramics, coins, weapons etc. was reopened in 2017 [2]. The castle is a historical monument of national as well as of European importance and is under the administration of the City Museum of Bratislava. Currently, there is ongoing archaeological and geological research in the area as well as plans for the reconstruction of ruins (the walls) and buildings at site. The caves as well as other areas with permanent exhibitions and the middle castle are threatened by humidity from precipitation; the dolomite cliff on which the castle is located is threatened by erosion and rockfall.

Figure 3: Devin Castle from the air. Photo: P. Chromek, Foundation for Cutural Heritage Preservation.

3.2 Cultural heritage at risk from climate change impacts

The historical monument reservation is greatly threatened by pluvial flooding, as a majority of the most valuable objects are preserved in situ. Additional moisture and humidity threaten these objects, and there is risk of closing the sites to the public in order to safeguard the health of visitors as well as to avoid further harm done to the monuments. A recently developed pluvial flooding model of Bratislava showed that the historical monument reserve is the most threated area by pluvial flooding in the city centre [4]. The remaining Devín Castle walls are threatened by the movement of the cliff as well as by the rapidly changing temperatures throughout the year. It is completely open how much time is left until Devín Rock finally erodes to an extent that the castle will have to be closed for visitors or – in the worst-case scenario – collapses into the Danube river. It would be highly useful for the Bratislava City Museum and Bratislava City and Devín city borough to know the trends of rock erosion and how they can be affected with regard to climate change scenarios. This would help the stakeholders determine which resilience options are suitable and in what intensity or volume they need to be implemented. Therefore, developing resilience option pathways for mitigation of the currently non-sustainable situation in the historical monument preserve and mitigation of erosion at Devín are priorities of Bratislava City, Municipal Monument Preservation Institute, Bratislava City Gallery and Bratislava City Museum.

After carrying out a first vulnerability assessment in 2018 to prioritise the most vulnerable sectors and groups, a second risk-oriented vulnerability assessment has been undertaken as part of a previous Horizon 2020 project, which analysed the impacts of recent heatwaves and pluvial flooding on the population and selected critical infrastructures. Bratislava would like to take a further step with focusing on additional sectors such as cultural heritage protection with the aim to adapt the historical centre and other valuable tangible cultural heritage sites to the impacts of future scenarios of climate change. The current Action Plan for Climate Change Adaptation reaches the end of its term in 2020, and a new action plan is already under preparation. The preparation phase of the action plan offers itself as a good opportunity for testing and co-creating the tools of the ARCH project.

In order to develop tools helpful not only to the city administration staff, but also to the city organisations which are in charge of the city museum and expositions or manage different urban subsystems, e.g. public space, public transport, technical infrastructures, etc., Bratislava City has established a local stakeholder group that supports the project implementation with their expertise and provision of input from the early stage in the project. The goal is also to be able to inform policy-making authorities in the area of climate change adaptation and cultural heritage preservation about the new norms and standards which the ARCH project shall also contribute to.

4. Conclusion

As a result of climate change, environmental conditions are changing rapidly. Combining climate change with urbanisation, environmental pollution, and the increased demands of civilization for food security, the world is currently globally exposed to one of the most extensive degradations in millions of years. Therefore, cities need a precise and high-resolution assessment, including prognostic climate models, in order to make fully informed decisions on territorial development. The creation of such documents requires the preparation of specific inputs, often dependent on local knowledge of the area and, of course, on the availability of various thematic data.

Bratislava is the Capital city of the Slovak Republic, a metropolis of European importance and as the historical hub of European migration routes from North to South (the Amber Route) and from East to West (the Lower Danube Route). The city is defined as the centre of regional and international business importance for the exchange of cultural and historical values of Eastern and Western Europe. The new approaches in planning process have an ambition to create a city with high quality of life for all its citizens including building measures and regulations to mitigate the effects of climate change and reserve cultural heritage. The city has been in the process of preparation of a modern and high-quality spatial plan, therefore new trends in territorial development, including the results of cooperation of international teams of experts, as well as the views of stakeholders is highly appreciated in Bratislava.

5. Acknowledgment

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HYPERION - A Decision Support System for Improved Resilience and Sustainable Reconstruction of historic areas

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Abstract

We introduce a research framework for downscaling the predicted/simulated climate and atmospheric conditions as well as associated risk maps down to the 1x1 km (historic area) scale, merging them with geohazard maps and integrating them with site and structure specific multi-hazard vulnerability functions to determine the time-varying risk for historical cities. Applying atmospheric modelling for specific Climate Change (CC) scenarios at such refined spatial and time scales allows for an accurate quantitative impact assessment of the estimated micro-climatic and atmospheric stressors. The ambition of this work, performed under the framework of the HYPERION EU-funded project, is to produce a comprehensive tool to assess the threats of CC in tandem with other natural hazards, visualize the built heritage and cultural landscape under future climate scenarios, model the effects of different adaptation strategies, and ultimately prioritize any rehabilitation actions to best allocate funds in both pre- and post-event environments.

Keywords – Climate Change; Cultural Heritage, Risk Assessment

1. Introduction

Recent studies [1] highlight the potential impact of Climate Change (CC) and geo-hazards (such as landslides and earthquakes) on historic areas hosting Cultural Heritage (CH) sites and monuments, which in turn yield significant adverse impacts on economies, politics and societies. The deterioration of CH sites is one of the biggest challenges in conservation; aspects such as building technologies/materials, structural responses, preventive measures and restoration strategies, resilience and adaptation methodologies must be considered. Currently there is no specific process towards understanding and quantifying CC effects on historic areas; combined with the limited strategies on CC-related issues, it becomes difficult to assess quantitatively and qualitatively the impact of various climatic and other parameters on the CH sites [2]. These issues form an integral part of the necessary support that should be provided to governmental bodies and cultural authorities to properly adapt their policies, in the short and long term, towards deploying sustainable mitigation plans and providing efficient reconstruction of the CH parts that have been damaged. Finally, the absence of social and communities' participatory aspects to the overall resilience and reconstruction planning of the historic areas is a main challenge to tackle.

In this paper we present a novel research framework, which aims to leverage existing tools and services (e.g., climate/extreme events models, and their impacts, decay models of building materials, Copernicus services, etc.), novel technologies (terrestrial and satellite imaging for wide-area inspection, advanced machine learning, etc.) to deliver an integrated resilience assessment platform, addressing multi-hazard risk understanding, better preparedness, faster, adapted and efficient response, and sustainable reconstruction of historic areas. This work, conducted under the framework of the HYPERION EU-funded project, which involves 18 different academic, industrial and local authority entities from 8 European countries, will take into account the local eco-systems in the CH areas, mapping out their interactions and following a truly integrated/sustainable reconstruction approach (technical, social, institutional, environmental and economic level), by incorporating active communities participation (using the PLUGGY social platform [3]) and by supporting new business models based on the concept of a "load-balancing" economy, (using an algorithm that acts like a "reverse proxy", distributing client traffic across different companies within the same sector) and offering financial risk-transfer tools (insurance, Catastrophe-CAT-bonds) that can ensure the immediate funds availability to fuel timely build-back-better efforts. In the following paragraphs we give an overview of the concept behind the research framework, the envisioned system components and methodology.

2. Methodology

The proposed framework offers an overarching strategy that includes risk management, protection, and preparedness as complementary strategies to prevent damages to CH sites, identify and ward off additional threats and promote adaptation, reconstruction and other post-disruption strategies to restore normal conditions to the historic area, as well as long-term strategic approaches to adapt to CC and to wield policy tools for economic resilience. To achieve that, HYPERION introduces a research framework for downscaling the created climate and atmospheric composition as well as associated risk maps down to the 1x1 km (CH site) scale. Applying atmospheric modelling for specific CC scenarios at such refined spatial and time scales allows for an accurate quantitative and qualitative impact assessment of the estimated micro-climatic and atmospheric stressors. The system performs combined hygrothermal (HT) and structural/geotechnical (SG) analysis of the CH structures (indoor climate, HVAC, moisture and air transfer through walls, roofs and foundations, and related strains and stresses) and damage assessment under normal (past) and changed (future) conditions (anthropogenic or/and natural disasters), based on the climatic zone, the micro-climate conditions, the petrographic and physical-mechanical features of building materials, historic data for the structures, the effect of previous restoration processes and the environmental/physical characteristics of the surrounding environment. The data coming from the deployed sensors are coupled with (and utilised also to update) simulated data over the wider CH area (under HRAP) and are further analysed through our data management system and support communities' participation and public awareness. The data from the sensors feed the DSS to provide appropriate adaptation and mitigation strategies and support sustainable reconstruction plans for the CH damages to the vulnerable assets. The HYPERION system ends up to an enhanced visualization tool with improved 4D capabilities (3D plus time) that can provide a simple and easy way for all relevant stakeholders to assess damage and risk. The produced vulnerability map (based on the produced climate risk regional models) will be used by the local authorities to assess the threats of CC (and other natural hazards), visualize the built heritage and cultural landscape under future climate scenarios, model the effects of different adaptation strategies, and ultimately prioritize any rehabilitation actions to best allocate funds in both pre- and post-event environments. The overall results will inform the employment of appropriate physical, organizational and financial tools to support resilience, including (a) structural rehabilitation interventions and associated policies (b) load-balancing reciprocal agreements between local businesses of the same type and (c) financial risk transfer tools (community/municipality insurance plans, single/multi-hazard insurance-linked securities) that can offer low-cost financing within hours of any extreme event, to jumpstart an immediate reconstruction effort. The aforementioned system will be evaluated in CH sites in Greece, Italy, Norway and Spain, representing different climatic zones. Table 1 provides a list of hazards to be considered per case study.

3. System goals

In order to achieve the delivery of an integrated resilience assessment platform, addressing multi-hazard risk understanding, better preparedness, faster, adapted and efficient response, and sustainable reconstruction of historic areas, a number of system goals have already been identified, as these are described in the next paragraphs.

Table 1. Potential Impacts of CC, geo-hazards and man-made threats on the selected demo-cases [5]

Hazard	Case Study			
	Granada	*Venice*	*Tonsberg*	*Rhodes*
Sea Level rise/ Flooding	Very Low	High	Very High	High
Temperature Increase (°C)	Very High (>4.1)	Very High (2 – 5.5)	Medium (3.1 – 3.5)	Medium (3.1 – 3.5)
Mean Precipitation – Summer (%)	-39.9 up to -20	-39.9 up to -20	–19.9 up to 0	≤ -40.0
Drought (%)	Very High > 18.0	High:16,1% - 18.0	Very Low: < 12,1 Very	Very High > 18.0
Landslide (L), Earthquake (E)	High (L)	High (E)	High (L)	Very High (E)
Atmospheric composition change	Very High	Very High	High	Medium

3.1 Reliable quantification of climatic, hydrological and atmospheric stressors

The system employs quality assessed numerical modelling results for selected CC scenarios in the historic areas under consideration, covering processes and interactions from the short-term to the long-term (10-60 years). These data will be used to estimate quantitative indicators for the potential impacts of CC on historic areas from the individual building to a regional level, including also aspects related to their aesthetics due to long-term exposure of the structures to air pollution and microclimatic conditions. Changes of both the average climate and the increase of the intensity and frequency of extreme climatic/weather events will be considered. A Land Surface model has been identified to account for the impact of climate and atmospheric composition on soil surface parameters (e.g., the presence of liquid water), thereby quantifying the structural and thermo-physical impacts on the structural elements [4]. The high-resolution modelling effort will exploit existing sources of climate and air pollution data enriched with sensor data (on site) and enhance their added value through risk indicators for selected risk hot-spots (e.g., foundations, facades of buildings), introducing a risk modelling interface with our resilience assessment platform.

3.2 Multi-Hazard modelling

This covers single, cotemporaneous (e.g., extreme temperature, humidity, wind, air pollutants) and cascading (mudflow/landslide after rain, etc.) hazards. Inundation maps will be provided for specific catchments by using hydrological modelling for various precipitation capacities, while seismic hazard will be quantified in terms of seismic intensity levels (peak ground acceleration, spectral acceleration estimates, and surface faulting deformations) and their spatial/temporal distribution for the historic area, by using stochastic modelling approaches (probabilistic seismic hazard analysis). HYPERION aims to provide input for the relevant regulatory framework, (e.g. Eurocode 1), on the load models for climatic actions. Data-based calibration of these models will be done at case-study level, and methodologies for evolution of these load models to take into account CC will be proposed.

3.3 Analysis of building materials and deterioration processes

Deterioration patterns and dose-response functions of building materials to be integrated in Heat, Air & Moisture (HAM) simulations are being developed for (a) classification of various building materials and damage assessment at demonstration sites, physical/mechanical characterisation of fresh, unaltered samples; (b) identification of critical first order factors that are not currently considered in the available recession models, and their measurement at CH-scale; (c) deterioration analysis of physical-mechanical properties of materials; (d) refinement of damage and dose-response functions; (e) effect of extreme events & environmental aging processes on deterioration of building materials.

3.4 Implementation of a Hygro-Thermal (HT) simulation tool

The tool considers the coupled HAM transport phenomena through structure's elements under specific scenarios. It characterizes the microclimate, both exterior and interior, using Computational Fluid Dynamics (CFD), models the hygrothermal performance of building materials that integrates boundary conditions obtained through transient CFD models, it validates these models using time-series experimental data, it quantifies the pace and magnitude of the change of material properties through comparative analysis between modern local materials and in-site materials, it analyses the CC risk scenarios in 1D, 2D and 3D spatial resolution and assesses CC impacts on acceleration of materials and elements degradation, and enriches the validated databases of hygric and thermal building material properties to be used simulations.

3.5 Improved prediction of Structural and Geotechnical (SG) safety risk

Using simulators that exploit monitoring data from various sensors, we are able to predict the SG safety risk. HYPERION will assess the current condition of structural, non-structural and content components of characteristic archetype buildings in the historic area. These detailed models will be leveraged to validate simplified surrogate numerical models or reduced-order physical models, achieve accurate pre-event and near-real-time (n-RT) post-event assessment of the impact of the climate pressure and geo-hazards, define related damage/vulnerability functions and capacity thresholds of the aging structure, optimise any reconstruction or retrofitting actions and finally evaluate the response of the structure in the future, for a large number of hazards scenarios with/without the proposed adaptation and mitigation measures.

3.6 Environmental and material monitoring including state identification and damage diagnosis:

Novel Computer Vision (CV) and Machine Learning (ML) algorithms will be implemented to exploit sensors, such as visible spectrum cameras, hyper-/multi-spectral cameras, thermal/infrared/Ultra-Violet sensors, mounted on vehicles and drones to get a precise inspection of CH sites.

3.7 Design of a Holistic Resilience Assessment Platform (HRAP) and a Decision-Support-System (DSS), enabling communities' participation.

HRAP will allow the integration of various analysis, modelling tools and damage/vulnerability functions, hence incorporating information from various sources (literature, surveys, satellite, etc.) with different levels of granularity (building/block/regional level) together with the associated uncertainties. All these tools will be built on a Geographic Information System (GIS), interfaced with existing open-source hazard assessment software and network simulators, and chained to socioeconomic impact analysis tools to produce both quantitative and qualitative loss estimates (e.g. financial loss estimate, reputation impact, morale impact etc.) in order to develop an end-to-end simulation platform enabling the running of any number of different "what-if" scenarios.

The platform will also support the community-based participatory environment through the PLUGGY social platform, for increased CH site participation and awareness. HRAP aims to integrate all the hazard and impact assessment tools and modelling data (climatic, SG and HT) in order to support decisions at strategic, tactical and operational level.

4. Conclusion

A novel research framework is proposed for downscaling the assessed climate and atmospheric conditions down to the 1x1 km (historic area) scale, merge them with geohazard maps and combine them with vulnerability data to determine the resilience of Cultural Heritage (CH) sites and associated cities. Applying atmospheric modelling for specific Climate Change (CC) scenarios at such refined spatial and time scales allows for an accurate quantitative and qualitative impact assessment of the estimated micro-climatic and atmospheric stressors. HYPERION will perform combined hygrothermal and structural/geotechnical analysis of the CH sites (indoor climate, HVAC, related strains and stresses, etc.) and damage assessment under normal and changed conditions, based on the climatic zone, the micro-climate conditions, the petrographic and textural features of building materials, historic data for the structures, the effect of previous restoration processes and the environmental/physical characteristics of the surrounding environment. The data coming from the integrated monitoring system will be coupled with simulated data (under our holistic resilience assessment platform-HRAP) and will be further analysed through our data management system, while supporting communities' participation and public awareness. The data from the monitoring system will feed the DSS so as to provide proper adaptation and mitigation strategies and support sustainable reconstruction plans for the CH damages. The produced risk map will be used by the local authorities to assess the threats of CC (and other natural hazards), visualize the built heritage and cultural landscape under future climate scenarios, model the effects of different adaptation strategies, and ultimately prioritize any rehabilitation actions to best allocate funds in both pre- and post-event environments. The project outcomes will be demonstrated to four European historic areas in Norway, Spain, Italy and Greece (representing different climatic zones).

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Data-driven and community-based resilience improvement of historic areas: SHELTER project

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Abstract

Over the last decades, as a consequence of the effects of climate change, cultural heritage has been impacted by an increasing number of climate related hazards, posing new challenges to conservators and heritage managers. Within SHELTER project, H2020 funded project, resilience thinking represents a dynamic view of the future where risk, uncertainty and surprises are the norm and are used to build a more sustainable system and a system-wide transformation. The project aims to establishing a cross-scale, multidimensional, data driven, and community based operational knowledge framework for heritage-led and conservation-friendly resilience that will bring together the scientific community and heritage managers with the objective of increasing resilience, reducing vulnerability and promoting better and safer reconstruction in historic areas. This operational knowledge framework will be the result of the interplay of two processes: a data driven platform that supports diagnosis, decision making, implementation and monitoring based on existing knowledge and heterogenous data, and an Open Labs approach that provides a continuous framework for local knowledge extraction, citizen´s engagement, co-creation, capacity building and innovation. These Open Labs will be developed in five complementary case studies: three Urban Open Labs (in Ravenna, Sefeherisar and Dordrecht) and two Cross-border Open Labs (in Sava River Basin and Baixa Limia-Serra). They have been selected according to the current and projected climate change challenges and natural hazards (earthquakes, flooding, wildfire, heat waves and storms) for the main regions in Europe and for the representativeness of diverse typologies of heritage (archaeological sites, natural landscapes, urban and rural and transnational sites).

Keywords – cultural heritage resilience; data-driven resilience; community-based resilience; historic areas

Session 10: Panel Discussion & Concluding Keynote

Session chair

Carsten Hermann, Historic Environment Scotland

Presentations

‘Meaning...what?’ Re-evaluating cultural heritage in a post-COVID-19 world

Graham Bell, Europa Nostra, England

Conference Reflections

Mairi Davies, Historic Environment Scotland, Scotland

Panel Discussion

Kirstine Møller, Memorial University of Newfoundland, Ilisimatusarfik – University of Greenland, Greenland

Mairi Davies, Historic Environment Scotland, Scotland

Jerker Bexelius, Stiftelsen Gaaltje, Sweden

Cathy Daly, University of Lincoln, England

Graham Bell, Europa Nostra, England

Marte Boro, Riksantikvaren, Norway

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