Impacts of climate change on cultural heritage

D. Harkin [1], M. Davies [1], E. Hyslop [1], H. Fluck [2], M. Wiggins [2], O. Merritt [2], L. Barker [3], M. Deery [4], R. McNeary [5] and K. Westley [6]

[1] *Historic Environment Scotland, Longmore House, Salisbury Place, Edinburgh, EH9 1SH, UK*
[2] *Historic England, Cannon Bridge House, 25 Dowgate Hill, London, EC4R 2YA, UK*
[3] *Royal Commission on the Ancient and Historical Monuments of Wales, UK*
[4] *Department for Communities, Heritage Advice and Regulation Branch, Northern Ireland*
[5] *DfC Historic Environment Division, Northern Ireland*
[6] *School of Geography and Environmental Sciences, Ulster University*

EXECUTIVE SUMMARY

- The United Kingdom is a maritime nation, with a rich and diverse record of past human occupation preserved on its coastline. This heritage provides a tangible link to the past and connects intangible stories to people and places. Many historic assets provide evidence of past environmental change that is crucial in developing an understanding of how future climate change will impact society.
- Cultural heritage is intrinsically linked to economic activity and contributes significantly to the economies of all parts of the UK.
- Changes in ocean temperatures, sea-level rise, coastal erosion, ocean acidification and altering patterns of extreme weather events all have the ability to impact cultural heritage underwater, in the tidal zone and on land. Many heritage assets are experiencing the negative impacts of these processes that are being exacerbated by climate change.
- The cultural heritage sector's response to these threats is well established, and has often taken a 'community-focussed' approach to managing the risks, through combining specialised skills in recording and surveying at-risk heritage assets, with the power and enthusiasm of local communities: thousands of sites have been recorded.
- National heritage organisations such as Historic Environment Scotland and Royal Commission on Ancient and Historic Monuments in Wales have developed and conducted various methods of assessing risk on coastal assets, with further developments planned.
- Ultimately, heritage organisations, local communities and other stakeholders may need to accept loss of coastal and marine heritage assets as an inevitability that is part of a natural process. Instead of viewing this as a failure, it can be seen as an opportunity to learn about the past in a way that would not have otherwise been possible.

Citation: Harkin, D., Davies, M., Hyslop, E., Fluck, H., Wiggins, M., Merritt, O., Barker L., Deery, M., McNeary R., and Westley, K. (2020) Impacts of climate change on cultural heritage. *MCCIP Science Review 2020*, 616–641.

doi: 10.14465/2020.arc26.che

Submitted: 05 2019
Published online: 15th January 2020.

1. INTRODUCTION

The United Kingdom is a maritime nation. The physical features and resources of the UK's varied coastline have influenced culture and sustained communities for millennia, through to the present day. As a result, the UK's coastline preserves a rich and diverse record of human activity dating back almost a million years. With that in mind, the relationship between our cultural heritage and the marine and coastal environments around the UK could not be more important. The term 'cultural heritage' encompasses a range of different facets. For the purpose of this review it focusses on tangible heritage, the physical remnants of the past that we can still see today. It is worth noting though that as climate change intensifies, intangible heritage will have an increasingly important role to play in preserving the memories, stories and traditions associated with the physical remnants that may disappear as a result of our changing climate.

There are many known historic sites situated on the UK's coastline. In Scotland, it is thought that the number of historic assets situated in coastal zones totals over 20,000 (The James Hutton Institute, 2013). In England there are over 37,000 assets recorded in coastal and marine zones (Historic England, 2018a). In Wales, analysis by the Royal Commission on Ancient and Historic Monuments in Wales (RCAHMW) has revealed that there are over 8000 historic assets at risk in the coastal environment (Powell *et al.*, 2012). In Northern Ireland, the Historic Environment Division (Department for Communities), hold records of over 2500 historic shipwrecks. Alongside this there is a significant number, and wide variety, of heritage assets located on its coastline (Breen, 1996; McErlean *et al.*, 1998). As well as these known historic assets found across the coastal and marine environments in the UK there are many thousands that are either undesignated and not recorded in official records, or yet to be discovered meaning calculating the true number of historic assets at risk from climate change is still very much a work in progress.

Lost landscapes

The UK's coastline is far from static: Our ancestors have had to deal with the impact of changing environmental conditions, just as we do today. Evidence of this can be found across the UK, in places like Happisburgh in Norfolk for example, where *Homo antecessor* footprints dating from 850,000 years ago were found exposed on a beach after a storm (Figure 1). Thought to be the oldest human footprints found outside of Africa, they were left in what was a muddy sedimentary deposit that would have been found in the lower stages of a river estuary, different to the beach environment they exist in today (Ashton *et al.*, 2014; Irvine, 2014).

Figure 1: View of exposed footprint surface at Happisburgh, Norfolk. Photos: Simon Parfitt (Ashton et al.*, 2014).*

The English Channel and North Sea in particular are home to submerged lost landscapes that once connected the British Isles to mainland Europe; this land bridge finally submerged around 8000 years ago. One of the more commonly referred to lost landscapes is that of 'Doggerland' (now beneath the southern North Sea) which has the potential to offer up crucial insights into prehistory (Gaffney *et al.*, 2009). Archaeology uncovered on the foreshore, such as the Happisburgh footprints, provide a means of investigating human life during a time when Doggerland was inhabited. Often these opportunities are short lived, with the same coastal processes that uncovered such finds ultimately destroying them. The potential for preserved and submerged prehistoric remains exists off the coast of Northern Ireland as well, as evidenced by intertidal/submerged Holocene peats, and isolated lithic finds recovered from the seabed by chance (Westley and Edwards, 2017).

A shifting shoreline also means that sites we perceive to be coastal today may not have always been as such. Skara Brae in Orkney, a Neolithic village occupied over 5000 years ago, was around 1 km inland when occupied. Today it is situated on the coastline with a modern sea-wall protecting the site from coastal erosion (see case study), having been uncovered during winter storms in the mid-1800s.

Figure 2: Oblique aerial image of Skara Brae. The site itself is protected by a sea-wall initially constructed in the 1920s. The softer, more-vulnerable coastline on either side of the sea-wall is clearly visible.(© Historic Environment Scotland.)

The information these lost landscapes hold in the archaeological record may provide valuable insights into what future conditions may be like under a changing climate. Indeed, the cultural heritage sector has many examples of investigating the long term nature of human-environment interactions with sea-level and coastal change. One such example is the The Lyonesse Project, a study of the evolution of the coastal and marine environment of the Isles of Scilly that was commissioned by English Heritage and conducted between 2009 and 2013. Understanding the impact of past (and present) sea-level rise on the Scilly Isles formed a major part of this project. The results were able to verify existing evidence that the isles were previously one single land-mass around *c*. 7000 BCE, taking on a form more familiar today around *c*. 1500 BCE (Perez, 2013).

Benefits of coastal settlement

The high density of historic assets in coastal zones is a result of past practices and needs of the people that chose to settle in such locations, as well as a result of a shifting shoreline. Proximity to the sea gave historical communities easy access to key transport and trade routes, which was particularly important in a historical context, as travelling by sea was often easier than travelling by land. The land in and around coastal zones has been used

intensively for agricultural and other industrial purposes due to its physical characteristics and ease of access to marine resources. For similar reasons it is often the site of key infrastructure, including roads, railways and fortifications. These combined elements still influence and shape our modern communities today, as they have done for millennia. Together they mean that the coastal zone in the UK preserves an irreplaceable record of human activity (Graham *et al*., 2017a, b).

Value of heritage

Cultural heritage is a valuable, and irreplaceable, record of human activity. Historic monuments, buildings and spaces shape how our towns, cities and rural areas look and feel. Our heritage provides us with a tangible link to the past and connects intangible stories to people and places. It provides many social, well-being and environmental benefits, including a sense of identity and a stimulus for community involvement, learning, leisure and recreational activities. The assets themselves even have a value in providing important habitats for marine flora and fauna, something particularly true of shipwrecks (Firth, 2015) see Figure 3.

Figure 3: A diver recording the wreck of HMS Montagu that sank off the coast of Lundy in 1906. Today the wreck site is somewhat obscured by a thick forest of kelp that the wreck supports. (Copyright Wessex Archaeology).

The management of heritage is intrinsically part of the solution to managing environmental change. In many cases, historic coastal assets may be designated, with management plans in place, meaning that these parts of the coastline are often better understood and valued, and, in some cases, better protected than adjacent landscapes. Where historic assets are designated the extent of land protected is often greater than the extent of the heritage asset

itself, meaning there is a key role for these assets to play in the management of shorelines. Providing a soft buffer against the energy of waves and wind means that these wider landscapes often play a sacrificial role in protecting other valued assets behind them.

The preservation of heritage and the historical character of a landscape has a positive effect on communities, while the ways in which heritage is managed can lead to a better understanding of the effects of climate change in other areas (Fluck and Wiggins, 2017). The archaeological record specifically is an important 'store' of past environmental data and provides a crucial long-term perspective on human vulnerability to changing environmental conditions (Jackson *et al.*, 2017) on a scale that other disciplines are often unable to achieve.

Cultural heritage is intrinsically linked to economic activity. In England, the heritage sector is estimated to support 459,000 jobs and attract over 236 million visitors each year, who spend approximately £16.9 billion (Historic England, 2018a). There is a similar picture in Scotland, where the heritage sector supports an estimated 54,000 jobs, contributes in excess of £2.3 billion to Scotland's economy and attracts over 14 million visitors every year, with this figure increasing year on year (Historic Environment Scotland, 2016). The historic environment contributes significantly to the Welsh economy, for example through tourism, heritage regeneration, employment and skills development. Heritage Counts Wales (2016) estimates that the historic environment contributes £932 million or 1.6 percent to Wales' economy and supports over 40,500 full-time equivalent jobs (Cadw, 2016). In Northern Ireland the historic environment generates approximately £532 million of output per annum, supports approximately 10,000 full-time equivalent jobs and generates approximately £250 million of Gross Value Added, each year (Department for Communities, 2012).

2. WHAT IS ALREADY HAPPENING?

Changes in ocean temperatures, sea-level rise, coastal erosion, ocean acidification (Willems and Schaik, 2017), and altering patterns of extreme weather events are influenced by climate change and all have the ability to impact cultural heritage underwater, in the tidal zone and on land (Croft, 2013). Additional impacts relate primarily to changing weather patterns, and include building-fabric degradation in response to changing rainfall patterns, air temperature and wind patterns (Sabbioni *et al.*, 2008), of course our built heritage has always been exposed to the natural processes of decay brought about by the climate they are exposed to. Climate change, as experienced today, is a threat multiplier and exacerbates the natural rates of decay that are expected. These damaging impacts of climate change have already been observed on a range of national heritage assets, and the way in which the historic environment is being conserved, preserved and researched, in light of

these new challenges, is being adapted accordingly. In some cases these changes have led to significant discoveries (Erlandson, 2012; Murphy *et al.*, 2009), as well as providing new opportunities for local people to interact and discover more about their heritage through participation in community projects. Approaches to managing these changes vary around the UK, and are influenced by different legislative drivers.

2.1 Legislative drivers

England

The Climate Change Act 2008 created a framework for the UK's response to climate change. In addition to measures to address climate change mitigation, the Act created a framework for climate change adaptation by establishing a cycle of Climate Change Risk Assessments, a National Adaptation Programme (NAP), and adaptation reporting. The NAP sets out what Government, businesses and society are doing to better adapt to climate change. This is informed by reports that are requested by Government from certain organisations under the Adaptation Reporting Power (ARP). The first round of reporting (2011) saw the government compel certain organisations to report. As part of the second, voluntary, round of reporting in 2016, Historic England submitted their climate change adaptation report (Fluck, 2016) which set out Historic England's priorities and commitment to climate change adaptation. At the same time, the Historic Environment Climate Change Adaptation Working Group (HEAWG) was established by Historic England and the Church of England to support the historic environment sector in reporting on climate change adaptation. Chaired by Historic England, the group continues to identify areas of mutual interest, coordinate research and facilitate partnership working in the heritage sector across the UK and Ireland.

Scotland

The Climate Change (Scotland) Act 2009 (the Act) places duties on public bodies to contribute to emission reduction targets, deliver programmes for adaptation, increase resilience, and to act in a sustainable way. Guidance on these duties published by the Scottish Government in 2011 makes it clear that public bodies are expected to assess the impact of climate change on their areas of responsibility and their daily operations, and build resilience. In response to the UK Climate Change Risk Assessment, published in 2017 (which itself was mandated under section 56 the UK Climate Change Act 2008) Scotland's second statutory Adaptation Programme was published in September 2019. This Programme sets out policies and proposals to prepare Scotland for the challenges that Scotland will face as a result of climate change. The Programme takes an outcomes-based approach, derived from both the UN Sustainable Devleopment Goals and Scotland's National Performance Framework. This cross-cutting approach promotes co-benefits, and integrates adaptation into the wider Scottish Government policy development and service delivery. The Historic environment features prominently in The Programme. HES is the lead public body for Scotland's

historic environment, and has taken this strong legislative foundation and created an informed and pragmatic approach to dealing with the impacts of climate change (Historic Scotland, 2012). HES has taken the strategic lead on this in Scotland, given its regulatory duties and status.

Wales

The Climate Change Act 2008 provides the central spine around which adaptation is organised in Wales. The UK Climate Change Risk Assessment (UK CCRA) provides the definitive analysis of risks facing Wales. The Act also places a duty on Welsh Ministers to report on their objectives, actions and future priorities in relation to adapting to the impacts of climate change. Sections of the Well-being of Future Generations (Wales) Act 2015 and the Environment (Wales) Act 2016 have been used to provide the mechanism for undertaking adaptation in Wales. For example, the Well-being of Future Generations Act requires the Welsh Government and the Public Services Boards (centred on local authorities) to take account of the UK CCRA when undertaking assessments and setting objectives at the national and local levels respectively. The Environment Act addresses climate change adaptation as part of its overall treatment of ecosystem resilience. The Welsh Government published its first Adaptation Programme in 2010 as part of its overall Climate Change Strategy. This was followed in 2012 by a comprehensive overview of climate change and the historic environment in Wales (Powell *et al*., 2012). The second National Adaptation Plan is currently being drafted and went out to consultation in December 2018. As well as a national adaptation plan, Wales' Historic Environment Group launched a sector specific adaptation plan for consultation in September 2018. This is a high-level, strategic document intended to identify climate change risks, opportunities and adaptation needs for the historic environment. Its aim is to stimulate action through strategies, programmes and partnerships.

Northern Ireland

The Climate Change Act 2008 also applies to this part of the UK. NICCAP (Northern Ireland Climate Change Action Plan) contains the Northern Ireland Executive's response to the risks and opportunities identified in the Climate Change Risk Assessment for Northern Ireland. The current plan was published in 2014 and a revised document is currently being developed for publication.

In regard to cultural heritage, the 2014 report included: implementation of the Protocol for the Care of the Government Historic Estate (NIEA, 2012), which had introduced a requirement that government departments take their heritage assets into account when preparing climate change action plans; the implementation of the recommendations of The Impacts of Climate Change on the Built Heritage Report (NIEA, 2010); and to raise awareness and engage with arms-length bodies with heritage assets. Progress on these high-level actions and key activities is being reported through a cross departmental

working group. The Department of Agricultural, Environment and Rural Affairs (DAERA), is the climate change policy lead.

Although not mentioned in the legislative framework, there are many heritage and NGO bodies who have developed large and climate-focused reporting and strategic approaches to coastal heritage management, the National Trust Shifting Shores project is a good example of this.

2.2 Impacts of climate change on coastal heritage

Impacts of sea-temperature change on heritage assets

Between 1984 and 2014, coastal water temperatures around the UK increased at an average rate of 0.28 °C/decade (Hughes *et al*., 2017). Warming seas have a variety of impacts on heritage assets, both direct and indirect. Indirectly, warmer seas are indicative of more-energetic conditions, meaning that rates of erosion experienced on the coastline may change to the detriment of coastal heritage (Willems and Schaik, 2017). Sea temperatures directly control the geographic range and abundance of species, with warmer waters around the UK allowing for migration of new and invasive species. Studies in ecology on wreck sites have highlighted the migration of invasive species to the UK in recent years. A study carried out by Bournemouth University for Historic England identified the presence of Blacktip shipworm (*Lyrodus pedicellatus)* on wrecks along the south coast, in Hampshire and Cornwall. These worms are thought to have migrated from southern latitudes as a result of rising sea temperatures. Significantly, this baseline research, completed in June 2014, records that the reported northern limit of *L. pedicellatus* by 1980 was at 40° N but by 2007 had extended to 50° N. Current records place *L. pedicellatus* around 51° N (Palma, 2014). A further study undertaken for Historic Scotland, limited to four wreck sites in Scottish waters, confirmed evidence for shipworm species considered to be locally established wood-boring communities. There was some evidence that archaeological wood may be particularly attractive to marine boring-molluscs. The Historic Scotland project provided very minimal evidence for *Teredo navalis* and *Lyrodus pedicellatus* and certainly not enough to state that they are as established as they are around the English coasts (Palma, 2016).

Impacts of sea-level rise and coastal erosion on heritage assets

Numerous studies have consistently estimated that the rate of regional sea-level rise (SLR) around the UK attributable to climate change, observed by tide gauge records , to be between 1 and 2 mm per year. When vertical land movement is also included, this rate is increased for the south of England and decreased for some parts of Scotland. These results are consistent with the globally averaged figure from tide gauge records of 1.7 mm per year between 1901 and 2010 (see accompanying MCCIP sea-level rise paper, Horsburgh *et al*., 2020). Rates of SLR are highly variable, with data showing that certain parts of the UK are now experiencing more-rapid rates of change. In Scotland,

for example, over the last 20 years rates of SLR measured at Scottish ports have exhibited a rate of increase of 3 mm/yr; this is faster than the 20th Century average (Hansom *et al.*, 2017; Rennie and Hansom, 2011). Rising sea levels have the ability to increase the severity of extreme sea-level events, such as exceptionally high tides, storm surges and severe weather events (Horsburgh and Lowe, 2013).

Combined, the impacts of SLR present an increasingly growing threat on coastal heritage. Increased rates of coastal flooding and erosion as a result of SLR have the ability to destroy coastal heritage gradually over decades, as well as catastrophic loss in single events (Hunt, 2011). A project to assess rates of coastal erosion in Scotland, 'Dynamic Coast: Scotland's National Coastal Change Assessment', used over 1 million data points summarising 2000 OS maps to see what historical and modern rates of coastal erosion were. The project mapped the changing position of Scotland's 'soft' coastline in 1890, 1970 and today, alongside future projections. The results show that, since the 1970s, there has been a 39% increase in the extent of erosion, with average erosion rates doubling to 1 m per year, compared with the historical baseline of 0.5 m per year (Hansom *et al.*, 2017).

The cultural heritage sector's response to these threats is well established, and has often taken a 'community-focussed' approach to managing the erosion of coastal heritage assets. SCAPE (Scotland), CITiZAN (England) and Arfordir (Wales) are three examples of organisations and collaborative projects that have empowered local communities and volunteers to record vulnerable coastal heritage before it is lost to the sea. Through combining specialised skills in recording and surveying at risk-heritage assets, with the power and enthusiasm of local communities, thousands of heritage assets around the UK's coastline have been recorded.

Between 2012 and 2016 SCAPE (Scottish Coastal Archaeology and the Problem of Erosion) recruited, trained and supported over 500 volunteers to conduct a national survey of 'at risk' coastal archaeology in Scotland. The aim of this survey was to update heritage data collected as part of Coastal Zone Assessment Surveys (CZAS) carried out for Historic Scotland between 1996 and 2010. The overall goal was to identify the most 'at risk' coastal heritage sites in Scotland. The review concluded that 31 sites required urgent action, including emergency excavation of archaeological deposits at immediate threat of being lost, and a further 114 remained vulnerable to the impacts of coastal process and extreme weather events (Hambly, 2017).

Figure 4: SCAPE conducting a survey in the River Clyde Estuary with local volunteers. The Titan Crane, Clydebank, is visible in the background – now a popular visitor attraction. (Copyright Tom Dawson/SCAPE.)

National heritage organisations such as Historic Environment Scotland (HES) have undertaken larger-scale strategic assessments of climate change risk. In 2018 HES published the first phase of its climate change risk assessment project. This phase detailed the risk to its 300+ Properties in Care from natural hazards such as flooding and coastal erosion. The project was carried out in partnership with the British Geological Survey and the Scottish Environment Protection Agency. Of the 352 sites analysed, they found that 31 were at high or very high risk of coastal flooding and 24 sites at a high or very high risk of coastal erosion (Historic Environment Scotland, 2018).

In Wales, a spatial mapping project led by the RCAHMW began in 2015. This project established a viable methodology by consulting a number of dynamic spatial data sets, including LiDAR, flood risk data and intertidal data, from a host of different organisations, to ascertain the number of historic assets that could be at risk from climate change (Cadw, 2018).

In England, English Heritage conducted an assessment of climate change risk on the 400+ historic assets it cares for 80 of these assets are located in the coastal zone, of these forty-eight were recognised to be at risk of flooding, while thirty-eight were deemed to be potentially at risk of coastal erosion (Hunt, 2011).

A strategic risk assessment of potential climate change impacts on archaeological heritage in Northern Ireland, which included coastal erosion and flooding was produced by Ulster University in 2013 (McNeary and Westley, 2013). The flooding component cross-referenced recorded heritage assets against projections of future flooding while the erosion component identified zones of erosion from aerial photographs and cross-referenced these against the position of recorded assets to estimate relative levels of vulnerability. This exercise concluded that visible coastal erosion was present across ?*c*. 15% of the Northern Ireland and particularly vulnerable areas (from a historic environment standpoint) in the immediate term were Strangford Lough (Figure 5) and the Foyle estuary. This was followed-up by a pilot study of the Foyle Estuary which used more-detailed ground and desk-based survey to verify the conclusions of the strategic overview and explore higher-resolution methods for quantifying erosion trends and asset prioritisation (Westley, 2015; 2018).

Figure 5: Nendrum tidal mill, Strangford Lough, Co. Down – the earliest excavated tide mill, dating from 787 AD. (DfC Historic Environment Division ©Crown Copyright).

Other examples from around the UK include extensive work in the Solent to understand the pace and scale of sea-level change. In 2014, the results of the EU-funded project 'Arch-Manche: Archaeology, Art and Coastal Heritage – tools to support coastal management and climate change planning across the Channel Regional Sea' were published (www.archmanche-geoportal.eu). The project sought to use historical documentary sources to develop an evidence base for furthering our understanding of the long-term patterns of coastal change that have resulted from climatic change and sea-level rise. Past trends were then calibrated by interrogating environmental data and datable material

in the intertidal and subtidal archaeological and palaeo-environmental archive.

A pilot project 'Coastal Risk Mapping and Communities' has been commissioned by Historic England to develop a methodology for assessing environmental risk to heritage assets along the coast. The project has developed an approach to scoring environmental risk against the vulnerability of heritage assets. It also highlighted the challenges of working with environmental data on a national scale (LUC, 2018). The project focussed on characterising key risks such as coastal flooding, erosion and sea-level change and found that in some cases, high resolution data was available but only on a regional scale, or that national scale data published in reports could not be sourced in a digital format. Historic England's own data required extensive processing to be interrogated on a national scale. The project used Environment Agency flood zones and National Coastal Erosion Risk Map to map coastal flooding and erosion, since it was struggling to find a suitable base for a national scale sea-level prediction model. Historic England will be looking to integrate forthcoming UK Climate Prediction 2018 (UKCP18) and an update to the BGS published Coastal Vulnerability Index in future rounds of work.

Impacts of ocean acidification on heritage

Atmospheric levels of CO_2 have increased from pre-industrial values of 280–300 ppm to average values now exceeding 400 ppm (Betts *et al.*, 2016). Oceans and seas play a crucial role in mitigating climate change by absorbing anthropogenic CO_2 emissions, removing 25–30% of CO_2 added to the atmosphere, this however causes acidification of the oceans. A more acidic ocean has the ability to negatively impact submerged metal structures and shipwrecks, lowering their preservation potential (Williamson *et al.*, 2017; Willems and Schaik, 2017). Many significant wrecks have been investigated by archaeologists, especially wooden sailing vessels that dominated shipping until the mid-nineteenth century. From around 1850 onwards, vessels made of iron and steel became the dominant form of ship. This change in material preference is reflected in the shipwreck record of the UK. Metal as a material however is unstable in seawater and as a result has a lower preservation potential than wood, which can survive in remarkable states of preservation if buried (Firth, 2018). In order to begin to understand the management requirements of metal-hulled vessels, English Heritage began an initial programme of research in 2012 (Dunkley, 2013). However, for accurate predictions to be made on the state of decay rates associated with ocean acidification, longer-term data capture is required. One aim of the CHERISH project (see case study below) is to gather baseline data from wreck sites within the intertidal zone, shallow water and deep water, to investigate both the physical, chemical and biological impacts of climate change (see Figure 6).

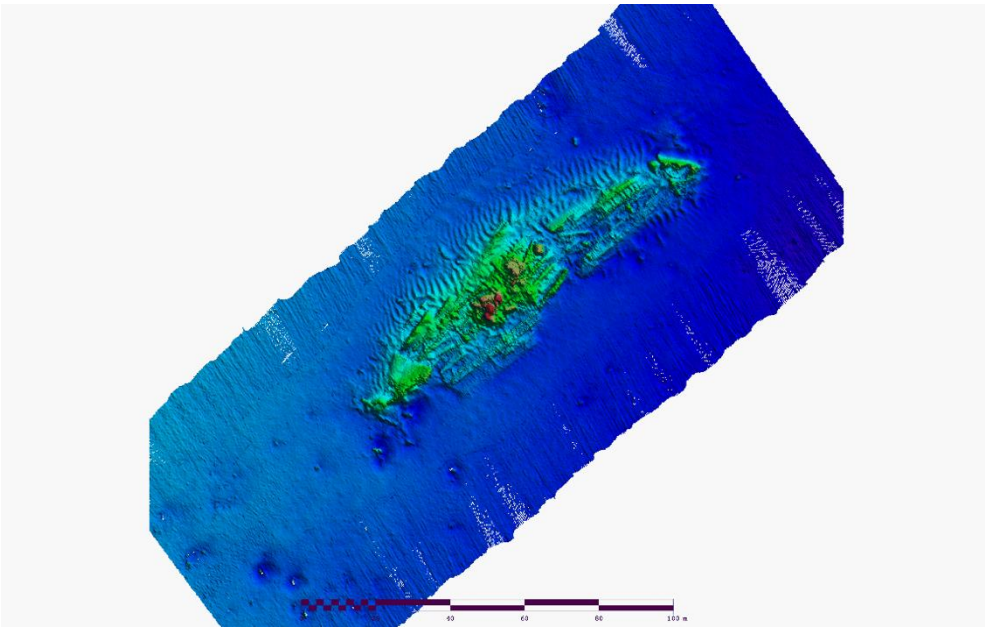


Figure 6: The SS IADHO was a British passenger ship built in 1869. In June 1878 while on a Voyage from New York to Liverpool via Queenstown after delivering mail to Queenstown she ran aground on Connigmore rocks near the Saltee Islands. The Idaho carried 151 passengers and a mixed cargo of 51 horses, some cattle and a 1000 tons of beef. She drifted off the rock and sank within 20 minutes, passengers and crew saved. The wreck was scanned as part of the CHERISH programme. (Crown Copyright: RCAHMW and CHERISH.)

3. WHAT COULD HAPPEN IN THE FUTURE?

The impacts of climate change over the next century will present serious challenges for our cultural heritage (Fatoric and Seekamp, 2017). The identified range of destructive or problematic impacts is numerous. For coastal cultural heritage this includes enhanced erosion rates and an increased probability of coastal flooding. Secondary impacts to onshore sites include changes in weathering (i.e. driven by wind, rain and temperature), while fully submerged sites may be affected by changes to seawater properties (pH, temperature) and hydrodynamic regimes. Adaptation or mitigation responses to climate change may also present challenges in the management of heritage. On the coast, for example, this is manifest by responses ranging from managed realignment to upgrading or construction of new sea defences. Underwater, potential impacts come via increased emphasis on offshore renewables and attendant infrastructure placed on the seabed, all of which have the potential to destroy or damage cultural heritage (McNeary and Westley, 2013, 48-49).

Whilst there is legislation from all regions of the UK that provide a statutory basis for protecting historic sites of interest, these obligations do not physically protect historic sites from the impacts of climate change, and it is climate change that is increasing the impact and destructive potential of these

natural processes. The relationship between rising sea levels and the frequency of coastal floods is clear in that the occurrence rates of flood events will increase (Hansom *et al.*, 2017). The IPCC AR5 has projected global sea-level rise for the period 2081 to 2100, compared to1986 to 2005, of 0.29 to 0.82 m. On a more-local scale, the expected SLR is likely to be different. For example, projections for the year 2100 (relative to the 1981–2000 average) contain considerable uncertainty. For London, the central estimate sea level projection for the year 2100 ranges from 0.45–0.78m, depending on the emissions scenario. Similar ranges of the central estimate at 2100 for other cities are: Cardiff 0.43–0.76m; Edinburgh 0.23–0.54m; Belfast 0.26–0.58m (Horsburgh *et al.*, 2020).

For heritage assets situated on the coast this means the future is uncertain. Those sites that have hard defences, such as sea walls, in place will inevitably need increasingly regular maintenance and adaptations to allow them to remain effective. Such defences are unlikely to remain the preferred solution for managing future risk at coastal heritage assets as they often cause or exacerbate damage in adjacent areas, alongside being costly to install and of high visual impact.

Where sites have no hard defence in place, solutions may be sought to try and restore the natural defences lost by erosion (see Links of Noltland Case Study, below). Where this is not possible, loss of heritage sites may have to be accepted, with programmes of excavation and recording conducted to document important information about the site before it is lost (see St Patrick's Chapel, Whitesands Beach Case Study). These different levels of intervention are currently being explored by organisations such as Historic Environment Scotland and the National Trust (see Figure 7).

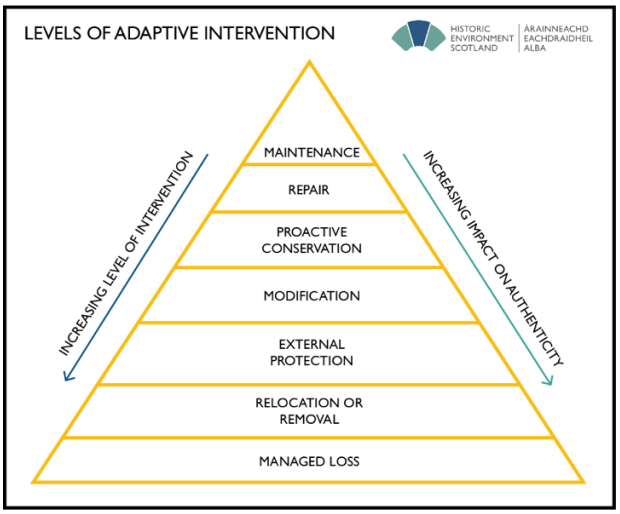


Figure 7: The different levels of adaptive intervention used in the management of coastal heritage assets, and the level of intervention and associated impact on authenticity they have. (Copyright Historic Environment Scotland.)

Ultimately, heritage organisations, local communities and other stakeholders may need to accept loss of coastal and marine heritage assets as an inevitability that is part of a natural process. However, instead of viewing this as a failure, it can be seen as an opportunity to learn about the past in a way that would not have otherwise been possible. There have been, and continue to be, many remarkable discoveries made as a result of coastal erosion, for example the aforementioned Palaeolithic footprints discovered in Norfolk. We only know of the presence of Mesolithic communities in the Western Isles of Scotland due to access to deep midden deposits, exposed as a result of coastal erosion in 2001 (Gregory *et al.*, 2005).

Ongoing work in the sector to assess risk and to identify the assets that are most vulnerable will help target limited resources and funds that can be used to excavate and record important sites before they are lost. The involvement of local communities in this process will be crucial. The importance of community-driven solutions to the loss of coastal heritage assets is exemplified in the relocation of the Meur Burnt Mound. This was originally uncovered by winter storms in 2005, and damaged in subsequent years by prolonged exposure to further winter storms. Faced with the prospect of total destruction of the site, the local community of Sanday, Orkney, in partnership with SCAPE, recorded, excavated and subsequently reconstructed the Meur Burnt Mound at their local heritage centre (Figure 8), using original fabric (Graham *et al.*, 2017a). Although the relocation of heritage assets is controversial, the reality is that this option may become increasingly important as climate change intensifies, particularly if driven by the enthusiasm of local communities who are keen to protect heritage assets that they value. There is acceptance, however, that this option would only be the solution for a small number of sites, it is however indicative of the changing approaches to managing cultural heritage that will be necessary as climate change intensifies.

Figure 8: Volunteers from the local community of Sanday, Orkney, guided by SCAPE archaeologists, excavating Meur Burnt Mound. (Copyright Tom Dawson/SCAPE.)

Supporting case studies

Skara Brae

Skara Brae in Orkney is one of the best preserved Neolithic villages in Western Europe and forms part of the 'Heart of Neolithic Orkney' World Heritage Site, as well as being a property in care of Historic Environment Scotland (HES). It was uncovered by a series of winter storms in 1850. In the 1920s a hard coastal defence was built to protect the site from further coastal erosion and this has been augmented at intervals, with repair and improvements ongoing. Aerial imagery clearly demonstrates that without this defence part of the site may have already been lost to coastal erosion, it is likely that the sea wall is contributing to increased rates of erosion on the unprotected soft-coast on either end of the protected area (Rennie *et al.*, 2017). In 2014 HES began a digital monitoring programme for the site. Every two years since then teams have visited the site to capture mm-scale accurate digital scans of the site and surrounding coastline to monitor how it is changing (see Figure 9). However, coastal erosion remains a threat to the long-term survival of the site (Historic Scotland *et al.*, 2014).

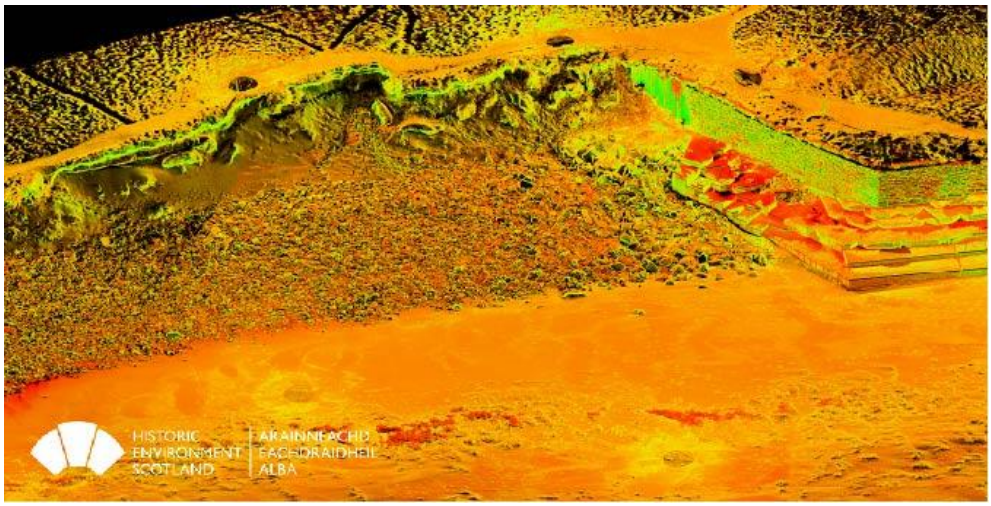


Figure 9: Sample of the digital data captured as part of HES' monitoring programme for the site showing an area of active erosion adjacent to the sea wall. (Copyright Historic Environment Scotland.)

CHERISH

CHERISH is a five-year (2017–2021) EU funded Ireland–Wales project, between the Royal Commission on the Ancient and Historical Monuments of Wales; the Discovery Programme, Ireland; Aberystwyth University: Department of Geography and Earth Sciences; and Geological Survey Ireland. It is a cross-disciplinary project aimed at raising awareness and understanding of the past, present and near-future impacts of climate change, storminess and extreme weather events on the rich cultural heritage of the sea and coast. It links land and sea and employs a variety of techniques and methods to study some of the most iconic and remote coastal locations in

Ireland and Wales. These range from terrestrial and aerial laser scanning, geophysical survey and seabed mapping, through to Palaeo-environmental sampling, excavation and shipwreck monitoring.

Figure 10: Dinas Dinlle, an Iron Age hillfort, one of the study sites selected as part of the CHERISH project. (Crown Copyright: RCAHMW and CHERISH.)

Historic Environment Scotland Climate Change Risk Assessment

In January 2018 Historic Environment Scotland (HES) published the first phase of its climate change risk assessment project. This phase detailed the risk to its 300+ Properties in Care from natural hazards, such as flooding and coastal erosion. The project was carried out in partnership with the British Geological Survey and the Scottish Environment Protection Agency. Of the 352 sites analysed, they found that 31 were at high or very high risk of coastal flooding, and 24 sites at a high or very high risk of coastal erosion. With many of HES sites situated on the coast these results were expected (like Tantallon Castle, Figure 11). HES now plans to refine the results of this assessment through measures like incorporating the new UKCP18 climate change projections into the assessment, ground-truthing the data and carrying out more in-depth desk-based studies of the properties to understand how the environmental conditions impacting their properties have changed in the past.

Figure 11: Tantallon Castle, a property in care of Historic Environment Scotland, overlooking the Firth of Forth. Sites like this, situated in strategic, easily defendable positions in the landscape exemplify the reasons why our ancestors chose to build in certain parts of the landscape that are today vulnerable to the impacts of climate change. (Copyright Historic Environment Scotland.)

Rapid Coastal Zone Assessment Surveys

Recognising that the historical environment of the coastal zone was poorly recorded since the late 1990s, Historic England (formerly English Heritage) initiated a programme of Rapid Coastal Zone Assessment Surveys to enhance the knowledge of the coastal historic environment in an effort to inform future Shoreline Management Plans (SMPs). The information gained has enhanced local Historic Environment Records (HERs), in some regions, such as North Kent the number of coastal heritage assets recorded has doubled as a result of the RCZA programme (Parham and Firth, 2001) and is therefore able to feed into SMP consultation and development. The project is ongoing and a second phase of assessment is now complete in many areas.

Links of Noltland

The site occupies some four hectares of sand dunes and coastal machair in Westray, Orkney. The area is subject to severe wind erosion and the dune system has been deflating since at least the 1980s. This erosion has led to the exposure of extensive and very well-preserved archaeological remains of Neolithic, Bronze Age and Early Iron Age date. Several interventions (monitoring, assessment, excavation and landscape consolidation) have been carried out since the late 1970s. The most extensive investigations commenced in 2006. Notable discoveries include the 'Westray Wife' – a carved stone figurine and the earliest human representation known from Scotland; a near-complete subterranean Neolithic house complex containing

two further figurines and numerous carved stones; a Neolithic carved stone ball, found *in situ* inside a house, and a near-complete subterranean Bronze Age ritual structure, interpreted as a sauna. In 2011, Historic Environment Scotland initiated an extensive programme of landscape conservation and grass planting to attempt to reconsolidate the dune system and allow this form of natural protection to re-establish itself. This has involved remodelling the dune scape to reduce wind speeds locally, and lower aeolian erosion rates, as well as planting marram and lyme grasses to stabilise and encourage the growth of new dunes. Recent inspections confirm that these measures have been effective and the area has been recolonised by vegetation (Moore and Wilson, 2011).

Figure 12a: Aerial view of Links of Noltland showing its exposed setting, and area of exposed dune system now extending inland. (Copyright Historic Environment Scotland.)

Figure 12b: Dune stabilisation works at Links of Noltland commenced in 2011 has involved the re-planting of Marram and Lyme grasses to try and restore the natural protection of the dune system. (Copyright Historic Environment Scotland.)

Ulster University and the Historic Environment Division – Lough Foyle Pilot Study

Research conducted as part of a broad-scale GIS-based erosion vulnerability assessment of the Northern Ireland coastline identified the Lough Foyle region as experiencing the highest level of coastal erosion (McNeary and Westley, 2013). A pilot study was undertaken for the Magilligan Foreland area of Lough Foyle in 2014 that incorporated the GIS-based Digital Shoreline Analysis System (DSAS) to quantify and analyze local shoreline change (Westley, 2015; 2018). DSAS allows calculation of rate-of-change statistics using past shorelines identified from georeferenced historical maps and vertical aerial imagery. Additionally, a field survey was conducted to assess the condition of archaeological sites. Results revealed a complex pattern of shoreline change in the study area, with zones of significant erosion interspersed with areas of stability or advance. The new information was used to develop a priority classification based on site significance, condition and risk level, which improved significantly on the uniform classification of the original broad-scale assessment (Westley, 2015; 2018).

St Patrick's Chapel, Whitesands Beach in Pembrokeshire

St Patrick's Chapel lies buried in sand dunes immediately above the high-tide level at Whitesands Beach in the parish of St David's, Pembrokeshire. Coastal

erosion has been affecting the site since at least 1924. Pembrokeshire Coast National Park Authority acquired the site in the 1970s and initiated a programme of stabilisation which included protecting the seaward face of the sand dunes with large boulders. These were washed away by the sea during the severe storms of the winter of 2013–14, were immediately replaced, only to be washed away again by more storms. Following the exposure of several long cist graves, it was decided to undertake a programme of excavation to recover the archaeology before more was lost to the sea. Thus, between 2014 and 2016, a 5-metre wide and 18-metre long strip of the eroding edge of the sand dune was fully excavated, and new protection constructed in the hope of providing a buffer against future erosion for decades to come. The deep stratigraphy of the site provided a wealth of archaeology, including a pre-cemetery phase of activity, and some 90 burials dating to the early medieval period. Dyfed Archaeological Trust undertook the excavation with funding from Cadw, The University of Sheffield and the Nineveh Charitable Trust with additional support from the Pembrokeshire Coast National Park Authority.

Figure 13: St Patrick Chapel, Whitesands Beach in Pembrokeshire undergoing emergency excavation. (Crown Copyright: RCAHMW.)

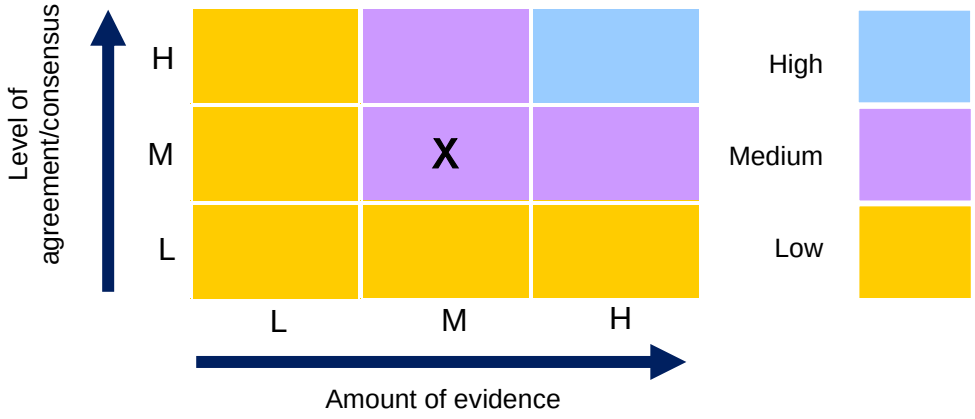
The National Trust; Shifting Shores

The National Trust cares for 775 miles of dramatic, diverse and ever changing coastline around England, Wales and Northern Ireland. In their 'Shifting Shores' report they commit to addressing the issues of coastal change on their properties by; working closely with communities, acting across boundaries

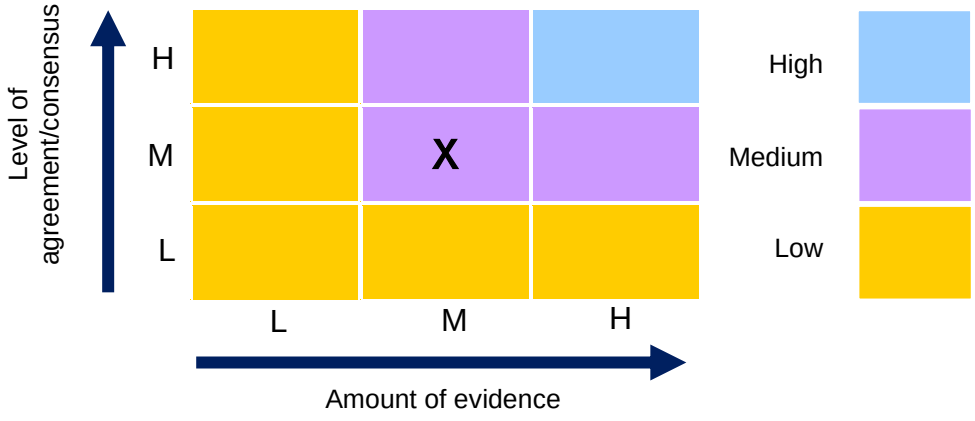
and joining forces with partners and people, innovating and having the courage to try out new ideas and finally, aspiring to have a healthy coastline, shaped by natural forces. At Birling Gap in East Sussex, plans for new buildings have been drawn up so they can roll back in advance of the existing buildings being lost due to coastal erosion. By 2020 they aim to have coastal adaptation strategies in place as a framework to inform community engagement and decision making for all their 80 coastal 'hotspots'.

4. CONFIDENCE ASSESSMENT

What is already happening



What could happen in the future?



The impacts of changing environmental conditions on the coastline on cultural heritage are well-understood in theory. Through monitoring, recording and surveying carried out by organisations and projects across the UK, there is a substantial amount of data already in existence. The rate at which climate change is accelerating these natural processes adds uncertainty

to what the future impacts will be, as well as a lack of data pertaining to the combined impacts of these processes. There is a greater understanding of the impacts of change on subsurface heritage assets in comparison to those that are fully submerged.

5. KEY CHALLENGES AND EMERGING ISSUES

The top three priority challenges and emerging issues which need to be addressed to provide better advice to policy makers are as follows:

(1) Communicating the emerging prominence of 'managing loss' of heritage assets as a result of climate change, and the need for more robust systems of prioritising assets for action. But equally demonstrating the value of heritage in understanding what the impacts of climate change are, how these assets have a valuable role to play in mitigating the impacts of climate change and in how they can motivate people to take action – the loss of something 'loved' or 'cherished' is often a catalyst for prompting people into taking action.

(2) The need for longer-term data capture to better understand the impacts of climate change on heritage assets. This includes understanding the impact of changes in ocean chemistry on decay rates of metal shipwrecks and changing rates of erosion on vulnerable coastlines (and projecting this into the future).

(3) Whilst we have increasingly good data on individual environmental threats e.g. sea-level rise, storminess, wind driven rain, storm surges etc., we do not understand how to quantifiably assess the impact of these in combination. This is when the damage will occur, not just from any one thing on its own.

REFERENCES

Ashton, N., Lewis, S.G., De Groote, I., Duffy, S.M., Bates, M., Bates, R. *et al.* (2014) Hominin Footprints from Early Pleistocene Deposits at Happisburgh, UK. *PLoS ONE*, **9**(2), e88329, doi:10.1371/journal.pone.0088329

Betts, R.A., Jones, C.D., Knight, J.R., Keeling, R.F. and Kennedy, J.J. (2016) El Niño and a record CO2 rise. *Nature Climate Change*, **6**, 806–810, doi:10.1038/nclimate3063

Breen, C. (1996) Maritime Archaeology in Northern Ireland: an interim statement. *International Journal of Nautical Archaeology*, **25**(1), 55–65.

Cadw (2016) *Heritage Counts Wales 2016*, https://cadw.gov.wales/docs/cadw/publications/heritage-counts-final-eng.pdf

Cadw (2018) *Historic Environment & Climate Change: Sector Adaptation Plan, Consultation Draft*, https://cadw.gov.wales/about/partnershipsandprojects/partners/histenvgroup/climatechange/?lang=en

Croft, A. (2013) *Assessment of Heritage at Risk from Environmental Threat*. Key Messages Report for English Heritage, https://research.historicengland.org.uk/Report.aspx?i=15749

Department for Communities, Northern Ireland (2012) *Study of the Economic Value of Northern Ireland's Historic Environment*, https://www.communities-ni.gov.uk/publications/study-economic-value-northern-irelands-historic-environment

Dunkley, M. (2013) Ultrasonic Thickness Testing: devising new ways to manage marine heritage, *Research News*, **19**, 30–31.

Erlandson, J.M. (2012) As the world warms: rising seas, coastal archaeology, and the erosion of maritime history. *Journal of Coastal Conservation*, **16**(2), 137–142.
Fatoric, S. and Seekamp, E. (2017) Are cultural heritage and resources threatened by climate change? A systematic literature review. *Climatic Change*, **142**, 227–254.
Firth, A. (2015) The Social and Economic Benefits of Marine and Maritime Cultural Heritage: towards greater accessibility and effective management. *The International Journal of Nautical Archaeology*, **46**, (1), 223–224, https://doi.org/10.1111/1095-9270.12228
Firth, A. (2018) *Managing Shipwrecks*. Fjordr Limited for Honor Frost Foundation.
Fluck, H. (2016) Climate Change Adaptation Report, Historic England, https://research.historicengland.org.uk/Report.aspx?i=15500
Fluck, H. and Wiggins, M. (2017) Climate change, heritage policy and practice in England: Risks and opportunities. *Archaeological Review from Cambridge*, **32**, 2.
Gaffney, V., Fitch, S. and Smith, D. (2009) *Europe's Lost World, the Rediscovery of Doggerland* (Cba Research Reports). Council for British Archaeology, York.
Graham, E., Hambly, J. and Dawson, T. (2017a) Learning from Loss: Eroding Coastal Heritage in Scotland. *Humanities*, **6**(4), 87.
Graham, E., Hambly, J. and Dawson, T. (2017b) Scotland's eroding heritage: A collaborative response to the impact of climate change. *Archaeological Review from Cambridge*, **32**, 2.
Gregory, R.A., Murphy, E.M., Church, M.J., Edwards, K.J., Guttmann, E.B. and Simpson, D.D.A. (2005) Archaeological evidence for the First Mesolithic occupation of the Western Isles of Scotland. *The Holocene*, **15**, 944–950.
Hambly, J. (2017) A Review of Heritage at Risk from Coastal Processes in Scotland. **574**, 2012–2016. Results from the Scotland's Heritage Coastal Heritage at Risk Project The SCAPE Trust, St Andrews, http://scharp.co.uk/media/medialibrary/2017/12/Review_of_Coastal_Heritage_at_Risk.pdf
Hansom, J.D., Fitton, J.M., and Rennie, A.F. (2017) Dynamic Coast – National Coastal Change Assessment: National Overview, CRW2014/2.
Historic England (2018a) *Heritage and the Economy*, https://historicengland.org.uk/research/heritage-counts/heritage-and-economy/
Historic England (2018b) *The National Heritage List for England*, https://historicengland.org.uk/listing/the-list/
Historic Scotland (2012) Climate Change Action Plan 2012–2017, https://www.historicenvironment.scot/about-us/what-we-do/climate-change/climate-change-action-plan/
Historic Scotland, Royal Society for the Protection of Birds, Scottish Natural Heritage and Orkney Islands Council (2014) *The Heart Of Neolithic Orkney World Heritage Site Management Plan 2014–19*, https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=c96546cf-ff4d-409e-9f96-a5c900a4f5f2
Historic Environment Scotland (2016) *Scotland's Historic Environment Audit*, https://www.historicenvironment.scot/advice-and-support/planning-and-guidance/scotland-s-historic-environment-audit/
Historic Environment Scotland (2018) *Climate Change Risk Assessment of the Properties in Care of Historic Environment Scotland*, https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=55d8dde6-3b68-444e-b6f2-a866011d129a
Horsburgh, K., and Lowe, J. (2013) Impacts of Climate Change on Sea Level, *MCCIP Science Review 2013*.
Horsburgh, K., Rennie, A. and Palmer, M. (2020). Impacts of climate change on sea-level rise relevant to the coastal and marine environment around the UK, *MCCIP Science Review 2020*, 116–131
Hughes, S., Tinker, J. and Dye, S. (2017) Temperature. *MCCIP Science Review 2017*.
Hunt, A. (2011) *English Heritage Coastal Estate: Risk Assessment*. English Heritage.
Irvine, R.D. (2014) The Happisburgh footprints in time: Environmental change and human adaptation on the East Anglian coast (Respond to this article at http://www. therai. org. uk/at/debate). *Anthropology Today*, **30**(2), 3–6.
Jackson, R., Dugmore, A. and Riede, F. (2017) Towards a new social contract for archaeology and climate change adaptation. *Archaeological Review from Cambridge*, **32**, 2 https://www.repository.cam.ac.uk/bitstream/handle/1810/276350/ARC32-2_Jackson_etal.pdf?sequence=1&isAllowed=y
The James Hutton Institute (2013) *Scotland's Coastal Assets*, http:// www.hutton.ac.uk/sites/default/files/files/publications/hutton_coast_ booklet_web.pdf
LUC (2018) *Coastal Risk and Priority Places*. Historic England Research Report Series.

McErlean, T.C., McConkey, R., McCooey, P. and Williams, B. (1998) *A Review of the Archaeological Resources of the Northern Ireland Coastline.* Unpublished Report for the Environment and Heritage Service.

McNeary, R. and Westley, K. (2013) *Climate Change and Cultural Heritage*. Unpublished Report for the Northern Ireland Environment Agency: Built Heritage Division.

Moore, H., and Wilson, G. (2011) *Shifting Sands: Links of Noltland, Westray: Interim Report on Neolthic and Bronze Age Excavations, 2007-09*, Historic Scotland.

Murphy, P., Thackray, D. and Wilson, E. (2009) Coastal Heritage and Climate Change in England: Assessing Threats and Priorities. *Conservation and Management of Archaeological Sites*, **11**(1), 9–15.

Northern Ireland Environment Agency (NIEA) (2010) *The Impacts of Climate Change on the Built Heritage of Northern Ireland*.

Northern Ireland Environment Agency (NIEA) (2012) *Protocol for the Care of the Government Historic Estate*.

Parham, D. and Firth, A. (2000) *North Kent Coast RCZAS Phase I 1999-2000*. English Heritage Research Report 123/2000.

Palma, P. (2014) *A Desk-based Assessment to Compile Baseline Information on Recorded Presence of the Shipworms* Teredo navalis *and* Lyrodus pedicellatus *in English Waters*. Unpublished report for English Heritage, ref. 6804.

Palma, P. (2016) *Monitoring Scottish Shipwreck Sites for the Presence of Marine Wood Boring Shipworms (MoSSS): End of Project Report*. Unpublished report for Historic Scotland.

Perez, M. (2013) A Palaeoecological approach to understanding the impact of coastal changes in Late Holocene societies using the Isles of Scilly as a case study. PhD Thesis, University of Plymouth.

Powell, J., Murphy, K., Ings, M., and Chambers, F.M. (2012) *A Strategic Approach for Assessing and Addressing the Potential Impact of Climate Change on the Historic Environment of Wales*, Report to Historic Environment Group – Climate Change Subgroup. CCRI, Gloucester.

Rennie, A. F. and Hansom, J. D. (2011) Sea level trend reversal: Land uplift outpaced by sea level rise on Scotland's coast. *Geomorphology*, **125**(1), 193–202.

Rennie, A.F., Hansom, J.D. and Fitton, J.M. (2017) *Dynamic Coast - National Coastal Change Assessment: Cell 10 – Orkney, CRW2014/2*, http://dynamiccoast.com/files/reports/NCCA%20-%20Cell%2010%20-%20Orkney.pdf

Sabbioni, C., Cassar, M., Brimblecombe, P. and Lefevre, R.A. (2008) *Vulnerability of Cultural Heritage to Climate Change*. Report prepared for the Council of Europe (EUR-OPA: European and Mediterranean Major Hazards Agreement).

Westley, K. (2015) *Foyle Climate Change Pilot Study*. Report prepared for the Northern Ireland Environment Agency: Historic Environment Division, 89 pp.

Westley, K. (2018). Refining broad-scale vulnerability assessment of coastal archaeological resources, Lough Foyle, Northern Ireland. *The Journal of Island and Coastal Archaeology*, **14**(2), 226–246, doi: 10.1080/15564894.2018.1435592

Westley, K. and Edwards, R. (2017) Irish Sea and Atlantic Margin. In: [Flemming N. et al. (eds)]. *Submerged landscapes of the European Continental Shelf: Quaternary Palaeo-environments*, Wiley, pp. 241–280.

Westley, K. and McNeary, R. (2014) Assessing the Impact of Coastal Erosion on Archaeological Sites: A Case Study from Northern Ireland. *Conservation & Management of Archaeological Sites*, **16**(3), 185–211.

Willems, W. J. and van Schaik, H.P. (2017) *Water & Heritage*: Material, Conceptual and Spiritual Connections Sidestone Press, Leiden.