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World Heritage and Tourism in a Changing Climate

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Foreword

From Venice and its Lagoon to the Galápagos Islands, some of the world's most iconic World Heritage sites are vulnerable to climate change. In this new analysis, the United Nations Environment Programme (UNEP), the United Nations Educational, Scientific and Cultural Organization (UNESCO), and the Union of Concerned Scientists (UCS) highlight the growing climate risks to World Heritage sites and recommend a clear and achievable response. Globally, we need to understand more about how climate change will affect all World Heritage sites, and how it will interact with and amplify the effects of other stresses, including urbanization, pollution, natural resource extraction and, increasingly, tourism.

There are more than 1 000 World Heritage properties in 163 countries and a great many of them are important tourist destinations. At its best, tourism drives economic development and brings needed financial and social benefits, but, as this report demonstrates, rapid or unplanned tourism developments, or excessive visitor numbers, can also have a negative effect on the properties. Climate change is likely to exacerbate existing stresses and bring direct impacts of its own. Sea-level rise, higher temperatures, habitat shifts and more frequent extreme weather events such as storms, floods and droughts, all have the potential to rapidly and permanently change or degrade the very attributes that make World Heritage sites such popular tourist destinations.

In adopting the Paris Agreement in December 2015, 195 countries acknowledged the importance of reducing greenhouse gases to a level that will keep global average temperature rise since pre-industrial times well below 2°C. Achieving this goal is vital for the future of World Heritage.

As this report shows, World Heritage properties provide opportunities for both climate mitigation and adaptation. For example, well-preserved forests and coastal habitats can help store carbon and provide vital ecosystem services, including natural protection against storms and floods. World Heritage sites can also act as learning laboratories for the study and mitigation of climate impacts, as well as being places to test resilient management strategies. Additionally, efforts can be made to increase visitors' understanding of the significance of the sites they visit and how climate change affects them, ensuring that responsible behaviours and practices support local communities and safeguard heritage assets.

The need to act is both urgent and clear. We must reduce greenhouse gas emissions in line with the Paris Agreement while providing the financial resources, support and expertise necessary to ensure the resilience of World Heritage properties over the long term. A growing body of knowledge, management guidelines and policy tools already exists that can help us achieve these goals. Success will require us to expand our networks and partnerships with local communities and businesses and to encourage the tourism industry to join us in this vital task.

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ABOUT THIS REPORT

This report provides an overview of the increasing vulnerability of World Heritage sites to climate change impacts and the potential implications for and of global tourism. It also examines the close relationship between World Heritage and tourism, and how climate change is likely to exacerbate problems caused by unplanned tourism development and uncontrolled or poorly managed visitor access, as well as other threats and stresses. Tourism can also play a positive role in helping to secure the future of many World Heritage sites in a changing climate.

The report's goal is to provide up-to-date information and a basis for action on climate change, tourism and World Heritage in the follow-up to the adoption of the Paris Agreement by the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015 and the 2030 Agenda for Sustainable Development, adopted by the United Nations General Assembly in October 2015.

Using a series of case studies from World Heritage sites around the world, many of them iconic tourist destinations, the report shows how climate-driven changes currently, or could in the future, threaten their outstanding universal value (OUV), integrity and authenticity, as well as the economies and communities that depend on tourism. The case studies were chosen for their geographic representation, diversity of types of natural and cultural heritage and importance for tourism. Most importantly, they provide examples of a wide range of climate impacts, supported by robust scientific evidence.

The 12 fully referenced case studies and 18 much briefer sketches provide examples from 31 World Heritage properties in 29 countries. An introductory section summarizes some of the common findings from the case studies and provides a situation report on the relationships between World Heritage, climate change and tourism. The recommendations lay out a series of priorities for the international community, national governments, the tourism industry and site managers.

The report was produced by UNESCO's World Heritage Centre, UNEP's Tourism and Environment Programme and the Union of Concerned Scientists (UCS), in close collaboration with the International Union for the Conservation of Nature (IUCN).

Executive summary

Yellowstone National Park, United States of America

Climate change is fast becoming one of the most significant risks for World Heritage sites worldwide. Unequivocal scientific evidence shows that concentrations of the main greenhouse gas, carbon dioxide, in the atmosphere are greater now than at any time in the past 800 000 years and that global temperatures have increased by 1°C since 1880. According to the Intergovernmental Panel on Climate Change (IPCC), some recent changes, including warming of the oceans and atmosphere, rising sea levels and diminished snow and ice, are unprecedented over decades to millennia. As temperatures continue to rise, heat waves will worsen, extreme precipitation events will become more intense and frequent, oceans will continue to warm and acidify, and the rate of sea-level rise will increase.

At many World Heritage sites, the direct and indirect impacts of climate change may present a threat to their outstanding universal value (OUV), integrity and authenticity. Climate change is a threat multiplier, and will increase vulnerability and exacerbate other stresses including, but not limited to, pollution, conflict over resources, urbanization, habitat fragmentation, loss of intangible cultural heritage and the impacts of unplanned or poorly managed tourism.

Most World Heritage sites are tourist destinations, and some are among the most iconic places on the planet. Tourism is one of the world's largest and fastest-growing economic sectors, responsible for 9 per cent of gross domestic product globally and providing 1 in 11 jobs. Tourism is heavily reliant on energy-intensive modes of transport including aeroplanes and automobiles. Currently contributing approximately 5 per cent of the global total, carbon emissions from tourism are predicted to more than double within 25 years.

Sustainable tourism can support the Sustainable Development Goals (SDGs) adopted in 2015 by the United Nations General Assembly (UNGA) in *Transforming Our World: The 2030 Agenda for Sustainable Development*, and promote the preservation of natural and cultural heritage.

If unplanned, uncontrolled or poorly managed, however, tourism can have a wide range of negative consequences for World Heritage sites and their local communities.

The tourism sector itself is vulnerable to climate change. Threats include more extreme weather events, increasing insurance costs and safety concerns, water shortages, and loss and damage to assets and attractions at destinations. Continued climate-driven degradation and disruption to cultural and natural heritage at World Heritage sites will negatively affect the tourism sector, reduce the attractiveness of destinations and lessen economic opportunities for local communities.

This report and its case studies demonstrate the urgent need to better understand, monitor and address climate change threats to World Heritage sites. Policy guidance that could steer efforts already exists – including the binding *Policy Document on the Impacts of Climate Change on World Heritage Properties* (http://whc.unesco.org/uploads/activities/documents/activity-397-2.pdf) adopted by the General Assembly of States Parties to the World Heritage Convention at its 16th session in 2007; sustainable tourism policy orientations that define the relationship between World Heritage and sustainable tourism, adopted by the World Heritage Committee at its 34th session in 2010 (http://whc.unesco.org/en/decisions/4240/); the ICOMOS International Cultural Tourism Charter Principles; and the 2006 *Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses.* Additional measures also need to be taken to increase the resilience of cultural and natural heritage, reduce the impacts of both climate change and unsustainable tourism and increase financing and resources for managing protected areas.

The report's full suite of recommendations can be found on pages 27–32.

The Prehistoric Sites and Decorated Caves of the Vézère Valley in France, with their famous prehistoric paintings, have been closed to tourists since 1963 owing to the deleterious effects of large numbers of visitors entering the caves.

Venice and its Lagoon, Italy

World Heritage and tourism in a changing climate

Climate change is one of the most significant risks for World Heritage to emerge since the adoption of the World Heritage Convention in 1972 (Box 1). Unequivocal scientific evidence shows that the concentration of the main greenhouse gas, carbon dioxide (CO_2), in the atmosphere is greater now than at any time in the past 800 000 years and that most of the increase has occurred since 1970 (IPCC 2014). Carbon dioxide emissions from fossil fuel combustion and industrial processes accounted for about 78 per cent of greenhouse gas emissions from 1970 to 2010. The tourism sector is responsible for about 5 per cent of global CO_2 emissions (Fischedick *et al.* 2014; UNWTO 2008), and the sector's emissions are projected to grow rapidly with increasing global travel.

Global temperatures have increased by 1°C since pre-industrial times (NASA 2016), and since the 1950s some of the changes, including the warming of oceans and the atmosphere, rising sea levels and diminished snow and ice cover, are unprecedented over decades to millennia (IPCC 2014). The 30-year period from 1983 to 2012 was probably the warmest in the northern hemisphere for 1 400 years (IPCC 2014), while there has been a 26 per cent increase in ocean surface water acidity since the beginning of the industrial era (IPCC 2014). The Intergovernmental Panel on Climate Change (IPCC), in its 2014 report, projected that global surface temperatures will rise through the 21st century under all assessed emission scenarios. Heat waves are very likely to occur more often and last longer; extreme precipitation events will become more frequent and intense in many regions; the oceans will continue to warm and acidify; and the rate of sea-level rise will increase (IPCC 2014).

To give just one example of the scale of the problem, coral reefs – which are represented in many tropical marine World Heritage sites – are particularly vulnerable to climate change and other environmental stresses. More than half of the world's reefs are at risk of degradation (Gattuso *et al.* 2014; Burke *et al.* 2011). According to the World Resources Institute, more than 275 million people worldwide live in the direct vicinity

Box 1 The World Heritage Convention and criteria for selection

Adopted in 1972, the World Heritage Convention protects natural diversity and cultural wealth of global significance, the importance of which transcends national boundaries (UNESCO). The roots of the convention lie in efforts during the late 1950s and 1960s to encourage international cooperation to protect cultural heritage and extraordinary natural areas for the benefit of future generations, and for all humankind. Properties included on the World Heritage List must meet at least one of ten criteria that demonstrate outstanding universal value. As of 2015, there were 1 031 properties in 163 countries on the World Heritage List and the Convention has 191 States Parties (UNESCO 2014a).

The concept of World Heritage, and the vital importance of linking natural and human systems and maintaining the balance between the two, is now well understood and supported worldwide. The World Heritage Convention helps bring attention to the world's most iconic and important cultural and natural heritage, provides support for management planning and implementation and monitors the state of conservation of the properties on the list. Inclusion on the World Heritage List can help drive tourism to properties, which if managed in accordance with principles of sustainable development can provide important economic benefits to local communities and national economies.

To be included on the World Heritage List, sites must be of outstanding universal value and meet at least one out of ten selection criteria.

(i) *To represent a masterpiece of human creative genius;*

(ii) *To exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or*

of reefs, at least 93 countries and territories benefit from tourism associated with coral reefs, and in 23 of these, reef tourism accounts for 15 per cent or more of gross domestic product (GDP) (Burke *et al.* 2011). Reefs worldwide are being directly affected by warming waters and ocean acidification, and climate change is also exacerbating other localized stresses (Gattuso *et al.* 2014; Hoegh-Guldberg *et al.* 2007). Even under the most ambitious current reduction scenarios for global greenhouse gas emissions, 70 per cent of corals worldwide are projected to suffer from long-term degradation by 2030 (Frieler *et al.* 2012), putting the reefs protected in many World Heritage sites at significant risk.

Coral reefs have persisted in tropical marine environments for several hundred million years and for at least the last 420 000 years have been able to adapt at the relatively slow rate of environmental change. Temperature change in the last 140 years, however, has been much greater and corals' ability to adapt is highly likely to continue to be outstripped by the rate of climate change in the coming decades (Hoegh-Guldberg 2012). Research suggests that preserving more than 10 per cent of the world's corals would require limiting warming to 1.5°C or less, and protecting 50 per cent would mean halting warming at 1.2°C (Frieler *et al.* 2012).

Climate change is both a direct threat and a threat multiplier. Worsening climate impacts are cumulative, and often exacerbate the vulnerability of World Heritage sites to many other existing risks, including uncontrolled tourism, lack of resources for effective management, war, terrorism, poverty, urbanization, infrastructure, oil and gas

technology, monumental arts, town-planning or landscape design;

(iii) *To bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared;*

(iv) *To be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history;*

(v) *To be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change;*

(vi) *To be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance (the Committee considers that this criterion should preferably be used in conjunction with other criteria);*

(vii) *To contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance;*

(viii) *To be outstanding examples representing major stages of Earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features;*

(ix) *To be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, freshwater, coastal and marine ecosystems and communities of plants and animals;*

(x) *To contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.*

(UNESCO: http://whc.unesco.org/en/criteria/)

development, mining, invasive species, illegal logging, hunting and fishing, competition for natural resources and pollution.

Higher temperatures are driving extraordinary environmental changes: the melting of polar ice sheets and glaciers; thawing of Arctic tundra; increases in extreme weather events, including more severe storms, floods and droughts; accelerating sea-level rise and coastal erosion; desertification; more and larger wildfires; and changes in species distribution and ecosystems. All of these changes are affecting World Heritage sites, both cultural and natural, in different ways.

Although there is potential for some species to move and shift their ranges in response to climate change in natural World Heritage sites, and many ecosystems exhibit some degree of climate resilience, adaptive capacity is reduced by other stresses including habitat loss, degradation and fragmentation. The speed of climate change and lack of habitat connectivity will severely limit ecosystem response in many cases, and will require the adoption of new and innovative management practices (Welling *et al*. 2015; Stein *et al.* 2014; Markham 1996).

Protecting large intact ecosystems is the most effective way of maintaining the adaptive capacity of natural World Heritage sites. For existing sites this means an increased emphasis on expanding and managing buffer zones and on ensuring connectivity between sites and other protected areas (Kormos *et al.* 2015). The need to adapt boundaries may be a significant issue for World Heritage sites in a changing climate, and in many

cases a larger or altered area may be needed to protect the outstanding universal value (OUV) of properties (UNESCO 2007a).

The monuments, buildings and archaeological treasures of cultural World Heritage sites, however, usually cannot move and are therefore inextricably tied to locality, place and living cultural practices and traditions (Australia ICOMOS 2013). Cultural resources lose part of their significance and meaning if moved and, once lost, they are gone forever (Jarvis 2014).

Historic buildings and monuments at World Heritage sites are vulnerable to climate-related damage from extreme wind and rainfall events, as well as from coastal erosion, flooding and increasing damp and other impacts. Building foundations can be destabilized by increases or decreases in soil moisture, changes in the freeze/thaw cycle or, at Arctic sites, by thawing permafrost. Climate fluctuations inside buildings – the effect of higher temperatures and humidity – can cause mould, rot and insect infestations (Sabbioni *et al.* 2008). Changes in temperature and water interactions are particularly important for earthen architecture, and many such sites – for example the Djenné mosque in Mali – are at risk from climate change (Brimblecombe *et al.* 2011). Rising sea levels in the Adriatic have already damaged hundreds of buildings in Venice.

Climate change and the World Heritage Convention

It has now been more than a decade since the issue of climate change impacts on natural and cultural heritage properties was formally brought to the attention of the World Heritage Committee (Welling *et al.* 2015). At its 29th session in Durban, South Africa in 2005, the World Heritage Committee called on States Parties to identify the properties most at risk from climate change and encouraged UNESCO "to ensure that the results about climate change affecting World Heritage properties reach the public at large, in order to mobilize political support for activities against climate change and to safeguard in this way the livelihood of the poorest people of our planet (Decision 29 COM 7B.a). This resulted in a ground-breaking report, *Predicting and Managing the Effects of Climate Change on World Heritage* (UNESCO 2007b), as well as the *Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses* (UNESCO 2007c). At its 30th session (Vilnius, 2006), the World Heritage Committee requested all States Parties to implement the strategy so as to protect the OUV, integrity and authenticity of World Heritage properties from the adverse impacts of climate change. In 2007, at its 16th session, the General Assembly of States Parties adopted a binding *Policy Document on the Impacts of Climate Change on World Heritage Properties* (UNESCO 2007a). Progress on implementing the strategy and the policy in most countries, however, has been quite limited to date. Furthermore, there has not yet been a comprehensive, science-based assessment of climate impacts and vulnerability at all World Heritage sites. Nonetheless, an increasing amount of data about climate change in relation to World Heritage sites has become available during the last decade or so.

A 2005 survey by the UNESCO World Heritage Centre found that for 72 per cent of properties for which responses were received from States Parties, climate change was acknowledged as a threat to natural and cultural heritage (UNESCO 2007b). In 2007, UNESCO identified a number of World Heritage sites at risk from climate change, including major tourist destinations such as Venice, Italy; Kilimanjaro National Park, Tanzania; Sagarmatha National Park, Nepal; and the historic centres of Český Krumlov and Prague in the Czech Republic (UNESCO 2007d). In 2014, a global analysis by researchers at the University of Innsbruck and the Potsdam Institute for Climate Impact Research identified more than 130 cultural World Heritage sites at long-term risk from sea-level rise, including India's Elephanta Caves, Mont-Saint-Michel and its Bay in France and the Archaeological Site of Carthage in Tunisia (Marzeion and Levermann 2014).

Also in 2014, the International Union for the Conservation of Nature's *IUCN World Heritage Outlook* declared climate change to be the most serious potential threat to natural World Heritage sites worldwide (Osipova *et al.* 2014a). Looking more widely at all types of threat, the report also noted that only half of all natural or mixed sites were routinely monitored; more than a third had serious concerns about the levels of conservation; and 13 per cent of sites had ineffective levels of protection and management. Monitoring threats and impacts of all types, including climate change, is critical for ensuring that sites retain their OUV status. In many countries, IUCN found that existing monitoring programmes and management were weak or insufficient (Osipova *et al.* 2014a).

Official reporting on threats to specific sites under the World Heritage Convention is through state of conservation (SOC) reports produced by the UNESCO World Heritage Centre and the advisory bodies – the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM), the International Council on Monuments and Sites (ICOMOS) and IUCN. The publicly accessible online World Heritage State of Conservation Information System contains many reports that identify climate-related threats (http://whc.unesco.org/en/soc). During the period 1979–2013, more than 2 600 SOC reports were submitted, with 70 per cent of natural and mixed sites and 41 per cent of cultural sites being assessed at least once. Some 77 per cent of all reports identified management and institutional factors as threats, including a lack of management plans or problems with implementing them; boundary issues; problems with legal frameworks and governance; and scarcity of financial or human resources. The second most reported category of threat was from buildings and development including housing, commercial and industrial

India's Elephanta Caves are one of 130 cultural World Heritage sites identified in a recent academic study as being at long-term risk from sea-level rise.

Traditional earthen buildings such as the Djenné mosque in Mali are particularly susceptible to changes in temperature and humidity.

developments, and visitor accommodation and associated infrastructure (UNESCO 2014b).

The UNESCO analysis shows that notification of climate change threats is increasing in SOC reports but, compared to what we know is actually happening on the ground, the issue is clearly still very significantly under-represented in reporting and threat assessment for World Heritage sites as a whole. Taking just the 30 case studies and sketches highlighted in this report, several have never had SOC reports prepared since their inscription, and for those that have, climate change has not always been identified as a threat, even when there is increasing evidence that this is the case. Despite the growing recognition of climate impacts in SOC reports, there remains a lack of comprehensive and detailed system-wide information and analysis available on the projected impacts of climate change on World Heritage sites and their vulnerability.

The *IUCN World Heritage Outlook* is repeated every three years for natural sites, but no such periodic assessment process yet exists for cultural sites. Both ICOMOS, through its Heritage at Risk reporting system (http://www.icomos.org/en/get-involved/inform-us/heritage-alert/heritage-at-risk-reports) and the World Monuments Fund, through its World Monuments Watch programme, address risks to cultural heritage, but neither has yet comprehensively included climate change matters within its scope, even though both have included specific case studies that address the risks posed by climate change. Several countries, including, for example, Canada, the United Kingdom (UK) and the United States of America (USA), have carried out or are in the process of completing comprehensive climate vulnerability assessments for individual World Heritage properties or for large portions of their protected area systems.

The Paris Agreement and Agenda 2030

With evidence of severe and accelerating climate impacts on World Heritage properties growing across the globe, and the need to reduce the risk to their OUV and associated tourist economies becoming more urgent, two recent international

agreements on climate change and sustainable development provide cause for cautious optimism. The historic Paris Agreement on climate change (UNFCCC 2015), adopted by 195 nations in December 2015 at the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC COP21), followed closely on the adoption by the United Nations General Assembly (UNGA) of *Transforming Our World: The 2030 Agenda for Sustainable Development* three months earlier (A/RES/70/1) (UN 2015). Together, these two international accords provide a new framework to guide governments in responding to climate change and steer them towards sustainable development. If implemented, they can support an enabling framework to protect World Heritage and tourism destinations for future generations.

The Paris Agreement (UNFCCC 2015) for the first time represents global consensus on capping global warming substantially "below 2ºC above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5ºC", a goal that all countries will contribute towards achieving through greenhouse gas emission reductions and other efforts. Governments agreed to work towards balancing emissions from carbon sources with removals through carbon sinks such as forests, so as to achieve zero net emissions in the second half of this century.

Three ground-breaking aspects of the Paris Agreement will be vital for the future management and preservation of World Heritage sites. First, the new emphasis on preventing deforestation will increase the importance of forest conservation efforts in World Heritage sites, their buffer zones and surrounding areas. Eighteen Latin American governments at COP21 pledged to use their protected area systems as tools for climate mitigation and adaptation. Key measures include carbon sequestration and preserving ecosystem services to reduce disaster risk, thus highlighting the positive role that natural World Heritage sites can play in national climate strategies. A recent IUCN study found that an estimated 5.7 billion tonnes of forest biomass carbon is stored within natural World Heritage sites in the pan-tropical regions of the world alone (Osipova *et al.* 2014b). Reductions in fossil fuel use will have the added benefit of reducing the number of World Heritage sites threatened by oil and gas exploration and development.

Secondly, the Paris Agreement highlighted the need to implement a new international approach to managing climate-driven disasters by shifting from a focus on reducing disaster losses to a comprehensive management vision – building on the *Sendai Framework for Disaster Risk Reduction 2015–2030* (UNISDR 2015) – that includes risk assessment, adaptation planning and resilience building.

Thirdly, the agreement established the potential for World Heritage sites to become key focal points for countries in building clean and resilient futures, and this may enable developing nations to access new support, including finance. Accountability is built in too, and every five years governments will come together to assess the collective contribution and measure progress towards the joint goal.

The ambitious new 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs) adopted by the UNGA in September 2015 (UN 2015) also offer an important opportunity for World Heritage. For example, unlike its predecessor – with its Millennium Development Goals (MDGs) – the 2030 Agenda addresses cultural heritage in the context of sustainable development for the first time. Target 11.4 of the SDGs calls for "strengthening efforts to protect and safeguard the world's cultural and natural heritage" and directly reflects the World Heritage Convention, which was the first international treaty to link these two elements. Goal 13 calls for taking "urgent action to combat climate change and its impacts". Goal 14's targets focus on sustainable use and conservation of the oceans, including minimizing and addressing the impacts of ocean acidification; conserving at

least 10 per cent of coastal and marine areas; and increasing the economic benefits to small island developing states through the sustainable use of marine resources, including through tourism. Goal 15 lays out targets for the restoration and sustainable use of terrestrial ecosystems – including forests, mountains, wetlands and drylands, and their biodiversity. And Target 8.9 calls for the development and implementation of sustainable tourism polices that promote jobs and local culture.

Together, the Paris Agreement and the 2030 Agenda can provide a road-map for governments to build inclusive societies, protect the planet from degradation, improve living conditions across the globe and maintain and preserve natural resources and cultural heritage. There is no time to be lost, however, as global temperatures have already risen by 1°C (NASA 2016).

Climate change and tourism

Tourism is one of the largest and fastest-growing economic sectors in the world, responsible for 9 per cent of global GDP and 1 in 11 jobs (UNWTO 2015). The international tourism sector ranks fourth behind fuels, chemicals and food and, at 6 per cent of global exports, higher than automobiles. Global tourism arrivals reached 1.18 billion in 2015 (UNWTO 2015).

Responsible tourism can be a driver of sustainable development and the preservation of natural and cultural heritage, but if unplanned and poorly managed it can be socially, economically and culturally disruptive and cause damage and degradation to sensitive ecosystems, landscapes, monuments and communities (WHC 2012). The 2011 ICOMOS *Paris Declaration on Heritage as a Driver of Development* (ICOMOS 2011) stated clearly that "local participation, drawing on local perspectives, priorities and knowledge, is a pre-condition of sustainable tourism development".

Tourism accounts for the largest movement of people across the globe (UNWTO 2015; ICOMOS 2001). International tourism is heavily reliant on energy-intensive transport modes, particularly aeroplanes and cars, and the sector's contribution to global carbon emissions, 5 per cent in 2005, is predicted to more than double by 2035. Some 75 per cent of emissions in the tourism sector are from transportation, and this segment is projected to triple its emissions from the 2005 baseline by 2035 (Fischedick *et al.* 2014). The industry is likely to come under increasing pressure to reduce greenhouse gas emissions (Nichols 2014), as this extraordinary growth, especially in long-haul travel, and the sector's reliance on fossil fuels are incompatible with the need to decarbonize the global economy enshrined in the 2015 Paris Agreement (Scott *et al.* 2016). One small step forward has been made since Paris. In February 2016, the Committee on Aviation Environmental Protection of the International Civil Aviation Authority for the first time issued a recommendation for a CO_2 emissions standard for aircraft that could be strengthened over time (ICAO 2016).

Tourism itself is highly vulnerable to climate change. Threats include changing weather systems and travel seasons at destinations, more extreme weather events, increasing insurance costs, water shortages and growing tourist exposure to some vector-borne diseases. Damage to cultural heritage, species loss and natural habitat degradation will also negatively affect tourism. Coastal tourism is the largest component of the sector globally, and will be heavily affected by rising sea levels, coastal flooding, beach erosion and worsening storm surges. For example, a 1-metre sea-level rise would be likely to inundate up to 60 per cent of the Caribbean region's tourist resort properties (Nichols 2014). Coral reefs contribute US$ 11.5 billion to the global tourism economy (Wong *et al.* 2014) and climate change is a major threat to these ecosystems.

Climate impacts at World Heritage sites will affect a broad range of tourism segments including beach and coastal vacations; the cruise industry; ecotourism; dive and safari tourism; nature and outdoor tourism including bird watching, hiking, trekking, climbing

Changes in populations of fynbos pollinating species, such as this Cape sugarbird feeding on a king protea, could have major implications for the ecosystems of the Cape Floral Region Protected Areas of South Africa.

and canoeing; cultural tourism; and visits to historic cities and buildings (UNWTO 2008).

Despite the growing body of academic research demonstrating the risks posed to tourism by climate change, concern remains low among tourism operators, with many wrongly believing that there is too much uncertainty around climate impacts to justify action and that adaptation will be relatively easy (Nichols 2014). In fact, adaptation options at many destinations are quite limited and there is an urgent need for the industry to address the issue more seriously. A 2008 report from the UNWTO and UNEP noted that the policy changes and investments needed for effective adaptation may take decades to put in place. The report called on the tourism sector to urgently begin developing and implementing response strategies, especially for destinations most likely to be affected by climate change by mid-century (UNWTO 2008). A recent academic assessment of the implications of the latest climate science for the tourism sector concluded that "the political and business case for a sectoral response on climate change has never been stronger" and "tourism absolutely cannot afford not to ... dedicate increased efforts to understand the implications of climate change" (Scott *et al.* 2016).

A recent study by the US National Park Service of the historical correlations between temperature and its 270 million annual visits showed that there is a strong relationship between climate conditions and park visitation. The study showed that park visits tend to increase with warmer weather, but that at temperatures of 25°C or above they significantly decrease. The authors suggest that climate change will have a large and potentially quite complex role in altering visitation patterns at protected areas worldwide and that managers need to take this into account in management and adaptation planning (Fisichelli *et al.* 2015).

Adaptation capacity in the tourism sector will vary. It is likely to be especially hard for communities and operators with large investments

Many natural World Heritage sites, including Kilimanjaro National Park, Tanzania, are vulnerable to climate change.

in infrastructure such as hotels, resorts, harbours and airports. These could become stranded assets, especially in heavily affected coastal areas. For all destinations, disaster preparedness and management will become an increasingly important part of any destination's integrated management plans as climate-related disasters worsen. Least developed countries, however, are more vulnerable to extreme events than richer ones, and so liable to suffer more.

Tourism and World Heritage

Tourism and World Heritage are natural partners. Almost all World Heritage sites are or become tourist destinations – some are among the most iconic places on Earth – and the objective of the World Heritage Convention is to protect sites of outstanding universal value for future generations. States Parties are required to "present" World Heritage properties to the public, and the inscription of a site on the World Heritage List brings responsibilities for protection as well as opportunities for community and economic progress through sustainable development (WHC 2010).

Tourism at World Heritage sites can provide considerable benefits for national economies as well as for the sites and their local communities, including bringing infrastructure development, economic opportunities, publicity and public awareness. Indeed, the potential economic benefits of tourism are often a major consideration in the nomination and inscription of World Heritage sites (Su and Lin 2014).

More than 40 per cent of all World Heritage sites are in Europe where there is already a thriving and diverse tourism industry. Seven of the top ten countries for international tourist arrivals are in Europe, with France the most popular, receiving around 80 million foreign visitors annually (Su

The Historic Centre of Český Krumlov, Czech Republic, is one of many historic cities at risk from catastrophic flooding as a result of more extreme weather events in a changing climate.

and Lin 2014). Tourism in less developed countries offers great potential for economic growth and sustainable development. Since the central concern of World Heritage sites is to preserve their OUV, this should serve as an incentive for communities and nations to properly manage tourism and protect their inheritance, including those assets that are most important as tourist attractions, so as to maintain the appeal for visitors sustainably over the long term. In this way, the growth of the tourism economy and the growth of the number of properties inscribed on the World Heritage List should, in concept, reinforce each other.

However, there are often negative impacts associated with uncontrolled or unplanned tourism development, including a lack of visitor access management, cultural disruption and poorly planned infrastructure such as airports, cruise ship terminals and hotels. Such developments can contribute to local environmental problems including excessive water consumption, water pollution, waste generation, habitat damage and threats to local cultures and traditions (UNEP and UNWTO 2012).

Tourists themselves can have a direct impact on sites, as is the case with visitors to Angkor in Cambodia (Delanghe *et al.* 2011) and scuba divers at Palau's Rock Islands Southern Lagoon (Poonian *et al.* 2010). Stonehenge in the UK now only allows access to a newly built visitors' centre rather than to the prehistoric site itself, so as to prevent damage to the stones; in France the famous Lascaux caves with their prehistoric paintings have been closed to tourists since 1963; and in Egypt, Tutankhamun's tomb will soon be closed and a replica built for tourists to visit instead. The last two sites have suffered significant deterioration caused by the humidity and temperature changes resulting from thousands of tourists entering their enclosed spaces.

If allowed to develop too fast, in an unsustainable way or without proper attention to issues of social equity and local impact, tourism can undermine the very assets that people want to visit. In the worst cases, little or no social or economic benefit accrues to local communities and the integrity of a site's OUV can be threatened or degraded.

The World Heritage Centre's assessment of SOC reports received from States Parties in 1979–2013 (UNESCO 2014b) analysed three impact categories associated with tourism, and found that 26 per cent of the SOC reports identified impacts of "tourism/visitor/recreation" as an issue, 14 per cent named "major visitor accommodation and associated infrastructure" and 10 per cent drew attention to problems caused by interpretation and visitation facilities. According to the analysis, the impacts of site visitor facilities are more often associated with cultural properties, whilst those of visitor accommodation and infrastructure occur more often at natural sites. "Tourism/visitor/recreation" problems were reported most frequently in the Asia Pacific and Europe/North America regions (UNESCO 2014b).

At its General Assembly meeting in Mexico in 1999, ICOMOS adopted the *International Cultural Tourism Charter* (ICOMOS 1999) with the objective of improving the relationship between host communities and the tourism industry. The charter principles, whilst not specifically designed for World Heritage sites, address some relevant management issues that can provide important guidance at the site level, for example on sensitivity to the needs of local communities, managing potential conflicts, site interpretation and tourism promotion. According to ICOMOS, "Tourism itself has become an increasingly complex phenomenon, with political, economic, social, cultural, educational, bio-physical, ecological and aesthetic dimensions. The achievement of a beneficial interaction between the potentially conflicting expectations and aspirations of visitors and host or local communities, presents many challenges and opportunities" (ICOMOS 1999).

Truly sustainable tourism development must manage issues of physical and cultural impacts at World Heritage sites and other destinations, as well as address the urgent necessity to reduce greenhouse gas emissions in this growing sector, especially from transport. At the same time, tourism should pay much greater attention to understanding and addressing the many and varied impacts of rapid climate change that will increasingly affect its operations and destinations.

Because of their international designation and the resulting resources and attention they receive, World Heritage sites have the potential to provide some of the best models and innovative examples of sustainable tourism. In order to realize that potential, however, and preserve the OUV that defines sites as so transcendentally important for future generations, sustainable and adaptive management strategies should be instituted to help make sites more resilient to climate change. UNESCO has produced a practical guide on climate change adaptation for natural World Heritage sites to help site managers better understand how climate change may affect the OUV of the sites and offer ideas for adapting to climate change with tailored management responses (Perry and Falzon 2014). Governments, too, are beginning to integrate climate issues with tourism planning. The best of these strategies have been collaboratively developed by protected area managers, scientists and public and private tourism stakeholders working together (GBRMPA 2009).

Table 1 illustrates the top 22 most reported impact categories at World Heritage sites for which SOC reports were submitted from 1979 to 2013 (UNESCO 2014b).

Gender issues in global tourism and climate change response at World Heritage sites

Gender equality is one of UNESCO's two global priorities (Olsson *et al*. 2014; WHO 2011). As women make up a large proportion of the tourism workforce, their full and equal involvement in climate preparedness and management strategies

associated with World Heritage sites and tourism destinations is vital. Even though women in tourism earn 10–15 per cent less on average than their male counterparts (UNWTO 2011), tourism can still offer them significant economic and leadership opportunities. The sector has almost twice as many female employers as any other economic sector, as well as a much higher proportion of self-employed women working on their own (UNWTO 2011).

The formal and informal opportunities for women in the tourism sector can make a significant contribution to poverty reduction in rural communities and thereby increase community resilience to climate change and other stressors

Table 1 The 22 most reported impact categories at World Heritage sites, 1979–2013

% of properties affected

0%	1–5%	6–10%	11–20%	21–30%	31–40%	41–60%	61–75%	76–100%

Specific factor negatively affecting the outstanding universal value of the property	Africa	Arab World	Asia-Pacific	Europe and North America	Latin America and Caribbean
Management system/management plan	81	84	77	58	75
Housing	28	51	32	38	43
Legal framework	22	29	22	18	41
Illegal activities	47	27	26	9	22
Impacts of tourism/visitor recreation	**16**	**24**	**32**	**25**	**29**
Ground transport infrastructure	16	27	27	20	28
Financial resources	47	14	20	8	26
Human resources	39	24	15	7	21
Management activities	14	29	23	15	21
Land conversion	28	20	10	3	21
Identity, social cohesion, changes in local population and community	27	20	11	2	21
Major visitor accommodation and associated infrastructure	**11**	**16**	**12**	**13**	**21**
Water (rain/water table)	14	16	10	7	12
Deliberate destruction of heritage	9	20	10	8	9
Livestock farming/grazing of domesticated animals	28	10	1	1	15
Mining	27	2	12	8	6
Effects arising from use of transportation infrastructure	3	14	10	8	18
Water infrastructure	14	8	10	6	12
Interpretative and visitation facilities	9	10	14	10	6
Solid waste	11	16	4	6	4
Erosion and siltation/deposition	13	14	3	4	6
War	22	14	0	1	0

Source: UNESCO 2014b (modified)

(UNWTO 2011). At the same time, however, climate-related damage to World Heritage sites can have a disproportionate economic effect on the women working in tourism. It is vital that the strategies and related tourism polices and measures implemented at World Heritage sites to address climate change be gender-responsive and support equality and empowerment.

Indigenous and local knowledge and cultural traditions can contribute to climate resilience

There is widespread recognition that indigenous and local populations have unique and valuable local knowledge, traditions and cultural practices that can contribute to effective management strategies in the face of rapid climatic change. The latest Intergovernmental Panel on Climate Change (IPCC) report notes, "throughout history, people and societies have adjusted to and coped with climate, climate variability and extremes, with varying degrees of success" (IPCC 2014). For this reason, cultural heritage provides an important resource, offering precedents alongside which today's social resilience and adaptive strategies for responding to climate change can be tested (Welling *et al.* 2015).

There is now a growing body of work, especially in the field of archaeology, that is helping to build an understanding of how human populations have adapted to short- and long-term climatic changes in the past (Dugmore *et al.* 2013), and which can provide both new data on environmental change of direct relevance to resource managers (Lotze *et al.* 2011) and an increasing number of well-documented cases of long-term adaptive and sustainable resource use by indigenous peoples (Hicks *et al.* 2016; Brewington *et al.* 2015).

Living cultural heritage is a vital resource for climate adaptation in and around World Heritage sites, and some aspects, including arts and crafts, dances and traditional agricultural practices, are increasingly popular draws for tourists, too. Indigenous and folk traditions are often some of the last traces of ancestral society and many have already disappeared through processes of globalization, mechanization, urbanization, emigration and other factors (UNWTO 2008). Many communities living in and around World Heritage sites, however, have developed a wealth of intangible cultural heritage in the form of knowledge and traditions associated with the sustainable management of biodiversity, forests, wetlands and marine resources, often over hundreds or even thousands of years.

Drawing on knowledge built up over generations, local community members can often observe and interpret climate phenomena in a different way, and at a richer and finer scale than can be done by scientists (Goswami 2015). It is commonplace for such traditional knowledge to be overlooked or ignored in planning and administrative decisions. There is, however, a growing number of World Heritage sites where local knowledge and community-based decision making are providing new models of resilience and adaptation. On the Pacific Island of Vanuatu, for example, traditional subsistence and construction practices, along with support networks based on kinship and exchange, form the foundation of cyclone preparedness and response strategies for the nation's sole World Heritage property, Chief Roi Mata's Domain (Ballard *et al.* 2015).

The practical experience deriving from the Community Management of Protected Areas for Conservation (COMPACT) initiative at several other World Heritage sites – including Tanzania's Mount Kilimanjaro and the Belize Barrier Reef – demonstrates that the involvement of indigenous peoples and local communities leads to management effectiveness and improved governance (Brown and Hay-Edie 2014).

ANALYSIS OF THE CASE STUDIES

Twelve fully referenced case studies are presented in this report, selected for their value in demonstrating the broad variety of climate change impacts that World Heritage sites are exposed to across the

globe. Climate-related impacts already being experienced at these sites include glacier melt, loss of seasonal sea ice, sea-level rise, coastal flooding and erosion, more intense storms and storm surges, higher atmospheric and ocean temperatures, changes in wildfire regimes and weather patterns, extreme rainfall, water scarcity, falling lake levels, drought and desertification, thawing permafrost and changes in species distribution.

All of the case study sites are nationally or regionally important for tourism, and several of them are iconic global tourist destinations, including the Galápagos Islands, Ecuador; Venice and its Lagoon, Italy; and Yellowstone National Park, USA. In addition to the case studies, the report includes information on 18 more World Heritage sites where climate change and tourism management issues interact and for which short sketches are provided to give a broader view of the situation around the world. Together, these provide a sample of World Heritage sites – with a range of low, medium and high levels of tourism development in 29 countries – that are already being affected by climate change or are likely to be highly vulnerable to it in the near future.

A number of the sites – including Greenland's Ilulissat Icefjord (Denmark); Shiretoko in Japan; the Ancient Ksour of Ouadane, Chinguetti, Tichitt and Oualata, Mauritania; the Rice Terraces of the Philippine Cordilleras; and the Heart of Neolithic Orkney (UK) – are already clearly being significantly and negatively affected by climate impacts.

At several of the sites where pressures resulting from visitor numbers, tourism development and infrastructure are already major stressors – including Rapa Nui National Park in Chile, the Galápagos Islands of Ecuador, the Italian city of Venice, and Ouadi Qadisha (the Holy Valley) and the Forest of the Cedars of God (Horsh Arz el-Rab) in Lebanon – climate change is an added problem, significantly increasing their vulnerability. Some of

Concern is rising over the impact of mass tourism on fragile sites, including Angkor in Cambodia.

the case studies and sketches profile sites where sustainable tourism or eco-tourism is an important part of national or local plans for economic development – such as Lake Malawi National Park, East Rennell in the Solomon Islands, and Coro and its Port in Venezuela – but where climate impacts threaten the success of those developments. In only one case, Greenland's Ilulissat Icefjord (Denmark), is climate change actually helping to drive tourists to the destination as visitors come to see one of the fastest-melting and most impressive glaciers in the world. The site is marketed and promoted as a place where visitors can see spectacular landscapes at the front-line of global climate change.

Two of the case studies – the Statue of Liberty, USA and Venice and its Lagoon, Italy – demonstrate the scale of financial resources that will be required for increasing the resilience of many World Heritage sites in a changing climate. To date, US$ 100 million has been allocated to the Statue of Liberty and adjacent Ellis Island for the restoration of utilities, services and visitor facilities damaged by Hurricane Sandy in 2012, and to ensure preparedness for the storms that are predicted to continue to increase in intensity in future, with more damaging storm surges resulting from sea-level rise. In Venice, work is almost completed on a project to build gates to prevent flooding, costing more than US$ 6 billion. To put these cases in context, the amount available to States Parties requiring international assistance to support site management through the World Heritage Fund totals just US$ 4 million – a drop in the ocean given the scale of response needed for the challenge of climate change.

Whilst several case-study sites have robust and successful visitor management strategies, few have attempted to comprehensively integrate both climate change and tourism into long-term sustainability planning. The conservation strategy for the Wadden Sea, along the coasts of Denmark, Germany and the Netherlands, provides one of the best examples of this philosophy in action.

In summary, several general conclusions regarding the interaction of climate change and tourism at World Heritage sites can be drawn from an analysis of the case studies:

- climate change can have a major negative effect on the attractions and assets that draw tourists to World Heritage destinations and thereby reduce the potential for economic and sustainable tourism development;
- over the long term the OUV, integrity and authenticity of some World Heritage sites could eventually be degraded by climate change to the extent that some properties may have to be added to the List of World Heritage in Danger and consideration eventually given to their de-listing;
- at World Heritage sites where tourism infrastructure developments and uncontrolled or poorly managed visitor access are already a problem, climate change impacts – for example, extreme weather events, coastal flooding and erosion – are likely to exacerbate problems and increase site vulnerability;
- climate change impacts have the potential to increase visitor safety concerns for the tourism industry, especially at sites where increased intensity of extreme weather events or vulnerability to floods and landslides are projected;
- national and regional tourism and development strategies and site visitor management plans, with very few exceptions, currently fail to take climate change impacts into account;
- climate change is too often regarded as a long-term potential problem for World Heritage sites rather than as an imminent or near-term issue, so assessment of climate vulnerability tends to be under-represented in state of conservation reports;
- site managers often lack the financial resources and expertise or training necessary to undertake comprehensive climate vulnerability assessments and the development and implementation of adaptation and resilience strategies.

Recommendations

The situation analysis in this report, along with the case studies and site sketches, demonstrates the urgent need to understand, monitor and respond better to climate change threats to World Heritage sites, as well as the interactions between climate change and the tourism sector. The requirements of the binding *Policy Document on the Impacts of Climate Change on World Heritage Properties* that was adopted by the General Assembly of States Parties to the World Heritage Convention at its 16th session (Paris, 2007), as well as the 2006 *Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses,* should be fully implemented. Additional action should be taken to increase the resilience of cultural and natural heritage and reduce the impacts of both climate change and tourism. These recommendations are intended for the international community, States Parties, government policy makers, the tourism industry and site management authorities.

INTERGOVERNMENTAL ORGANIZATIONS, THE WORLD HERITAGE CONVENTION AND ITS STATES PARTIES

The policy on responding to climate change adopted by the General Assembly of States Parties to the World Heritage Convention at its 16th session should be fully implemented

The *Policy Document on the Impacts of Climate Change on World Heritage Properties* requires that States Parties "ensure they are doing all that they can to address the causes and impacts of climate change in relation to the potential and identified effects of climate change (and other threats) on World Heritage properties on their territories".

States Parties are asked to consider site-level monitoring, mitigation and adaptation measures and establish thematic, global and regional links to understand, access, fund and implement mitigation and adaptation strategies. These efforts should be coordinated with other conventions and international bodies. States Parties should work to build public awareness and knowledge of climate change and its potential impacts on World Heritage properties and their values. The policy also calls for more research and research funding partnerships to better understand the consequences and costs of climate change for World Heritage sites as well as for societies, particularly traditional ones, or in sites such as cultural landscapes where the way of life contributes to their outstanding universal value (OUV). Consideration should be given to updating the World Heritage Committee's *Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses* in the light of the most up-to-date knowledge on site vulnerability and management options, potential resilience strategies and the latest climate science. Research, including on climate change, should continue to inform the implementation of the convention and management responses.

Identify those World Heritage sites most vulnerable to climate change and strengthen systems for continued assessment, monitoring and early warning of impacts

Despite efforts to address gaps in knowledge, information and capacity, there is still a need to undertake a comprehensive global review of the climate vulnerability of World Heritage sites, identify those that are most at risk and assess the threat to their OUV, integrity and authenticity. This review should take account of the interaction of climate change with existing stressors such as tourism pressures, illegal harvesting of natural resources, oil and gas developments, armed conflict and poverty. Systems for monitoring and early warning of climate change impacts should be developed and implemented. UNESCO, working with other international organizations including the United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP), International Labour Organization

(ILO), United Nations Industrial Development Organization (UNIDO) and the World Tourism Organization (UNWTO), should prioritize the mapping of impacts using World Heritage properties to field test management strategies and approaches in order to improve resilience and minimize impacts from climate change.

The World Heritage Committee should reinvest in implementing one of the key principles as defined by the *Policy Document on the Impacts of Climate Change*: to use existing tools of the World Heritage Convention and its operational guidelines, such as the List of World Heritage in Danger, and processes including reactive monitoring and periodic reporting, when considering the threat posed by climate change to the OUV, authenticity and/or integrity of a World Heritage property (UNESCO 2007).

Make climate vulnerability assessment part of the World Heritage site nomination and inscription process

Because of the potential for climate change to alter or significantly damage heritage values, climate change projections and vulnerability should be considered by States Parties when entering sites on to the Tentative List and when submitting their World Heritage nominations. In their evaluation of the nomination files put forward by the States Parties, the World Heritage Committee and its advisory bodies should also take climate change effects into account in accordance with the *Policy Document on the Impacts of Climate Change.*

To strengthen resilience to climate change, increase the inclusion of wilderness areas on the World Heritage List, ensure connectivity between sites, and increase resources for protected area management

Protecting large intact ecosystems is the most effective way of maintaining the adaptive capacity of natural World Heritage sites. For existing sites this means putting greater emphasis on expanding and managing buffer zones and on ensuring connectivity between sites and other protected areas (Kormos *et al.* 2015). Increasing the inclusion of wilderness areas with outstanding universal value within the World Heritage Convention will help maintain the large-scale ecosystem processes and biological diversity that are essential for adaptation and resilience in a changing climate and for maintaining the integrity of many sites (Kormos *et al.* 2015). Governments with protected areas already inscribed on the World Heritage List should step up implementation of existing management plans and policies already established under the World Heritage Convention or other multilateral agreements such as the Ramsar Convention on Wetlands and the Convention on Biological Diversity (Watson *et al.* 2014). In addition, a paucity of resourcing needs to be addressed urgently, both by States Parties and by the international community.

Urgently address the issue of inadequate resourcing for World Heritage site management and climate adaptation

Inadequate resourcing is the leading cause of poor performance in protected area management (Watson *et al.* 2014). Lack of resources, including financing, personnel, training and capacity building, represents the greatest barrier preventing effective management of World Heritage sites, including the assessment of their vulnerability to climate change, developing and implementing climate adaptation and resilience strategies, and planning and managing tourism development. Until World Heritage sites receive adequate public- and private-sector funding and resources, they will struggle to meet their preservation objectives. The tourism industry can demonstrate leadership by developing and participating in innovative partnerships that bring new financing in support of World Heritage site management.

Include cultural heritage in climate vulnerability assessments and policy responses at all levels, from the local to the international

Cultural heritage is not just a casualty of climate change; it is also a source of resilience and, therefore, part of the solution. Neither the

knowledge gained from living and past cultures, including from cultural heritage represented under the World Heritage system, nor the value of heritage lost or at risk of loss, has yet been effectively addressed in international scientific assessments of climate change such as the reports of the Intergovernmental Panel on Climate Change (IPCC) (UCSUSA 2014; INTO 2011). The IPCC should include and fully integrate cultural heritage in all future assessment reports. Cultural heritage and climate impacts on cultural World Heritage sites must also be more comprehensively addressed in climate policy responses. The 2014 *Pocantico Call to Action on Climate Impacts and Cultural Heritage* (UCSUSA 2014) and its call for mechanisms to ensure that cultural heritage voices and expertise are represented in climate policy discussions at all levels from the local to the international should be heeded.

Analyse archaeological data and cultural heritage to use what can be learned from past human responses to climatic change to increase climate resilience for the future

Some of the archaeological resources that can provide insights for our future by opening windows on the past are in danger of being lost, particularly in rapidly warming Arctic regions and along eroding coastal and riverine sites. An international response is needed to identify the sites most at risk and to synthesize and use lessons gleaned from the archaeological record and cultural heritage that can help with the development of adaptation strategies for natural and cultural heritage (IHOPE 2015; Jarvis 2014; Rockman 2012).

GOVERNMENT POLICY MAKERS AND THE TOURISM INDUSTRY

Develop strategies and polices that lead to greenhouse gas emission reductions from the tourism sector that are in line with the goals of the Paris Agreement

Carbon emissions from transportation and accommodation in the tourism sector are predicted to triple by 2035 and the paucity of technological mitigation options, especially for the rapidly growing long-haul travel sub-sector, means that emissions related to tourism are likely to continue to grow (Fischedick *et al.* 2014) unless sector-wide action is taken. The response from the industry needs to be on a scale that can match the seriousness and urgency of the problem (OECD 2011). The sector, including the travel and aviation industries, large international tour operators, small businesses, resorts and destinations, must address the issue of its emissions growth. Operators should audit, monitor and reduce their carbon emissions and minimize other environmental impacts. Sector-wide strategies and policies will require the development and adoption of less energy-intensive transportation and accommodation operations and the promotion of sustainable tourism.

Create detailed climate change action strategies for tourism management and development at vulnerable sites

Multi-stakeholder climate change strategies for tourism should be developed for sites where climate change has been identified as a current or future threat to their OUV, or where climate and tourism impacts together are increasing the vulnerability of the site and local communities. States Parties should work together with site management authorities, local communities, research institutions and the tourism industry to create strategies that:

- raise awareness of the OUV of natural and cultural sites and their importance as key assets for the tourism sector;
- provide a framework for the tourism industry to respond to climate change, including reducing their own carbon emissions;
- engage tourism operators in action that contributes to stewardship in the context of a changing climate;
- help to leverage resources in support of climate preparedness and resilience;
- provide a coordinating mechanism for government and the tourism industry to address policy and management issues to ensure an adequate response to climate change.

Fully integrate climate change impacts and preparedness into national and site-level tourism planning, policies and strategies

The importance to tourism of preserving World Heritage sites in a changing climate must be emphasized, recognized and understood by all involved in tourism planning at the national level, and in the public and private sectors. The management of World Heritage properties for tourism needs to take climate change vulnerability and protection into account. The potential impacts of climate change on the value and integrity of World Heritage sites, as well as the interactions between climate and tourism that could exacerbate negative effects, should be fully considered and integrated into national, regional and local tourism strategies and management. The current lack of integrated cross-sectoral assessments that analyse the full range of potential impacts and their interactions needs to be addressed urgently (Scott *et al.* 2016). Site management plans should closely reflect the predicted operational risks and potential impacts of both climate change and tourism.

In view of limitations on human and financial capacity in many developing countries, the task of managing and monitoring World Heritage sites will need to be widened to other sectors such as tourism. The use of innovative and layered approaches involving multiple partners and stakeholders pooling their talents and resources will improve short- and long-term planning, and strengthen monitoring and protection efforts. The coordination capacity of national World Heritage authorities will also require assistance and support from key tourism stakeholders. In particular, tourism promoters and management agencies must be tasked with raising the levels of awareness in their value chains of the vulnerabilities of World Heritage sites and encouraging a coordinated response.

Develop management tools for collecting data on tourism and climate impacts

It is important to develop tools for evaluating the role of heritage and its enhancement in the context of tourism planning and development; to assess the socio-economic cost of the degradation of heritage values and heritage assets resulting from tourism and climate impacts; to help define and test best practices to ensure the long-term preservation of the cultural and economic resource; and to facilitate combined tourism development and climate impact assessment.

Implement polices and action on climate change and tourism that are gender-responsive and participatory

Women should have an equal voice in decision making on climate change responses as well as equal access to resources (Perry and Falzon 2014) and economic opportunities in the context of World Heritage management and sustainable tourism. Achieving gender equality and women's empowerment in tourism will increase community resilience to climate impacts (UNESCO 2014). The public and private sectors must take proactive steps to mainstream gender in tourism policy, planning and operations; protect women's rights; and facilitate women's education, leadership and entrepreneurship in tourism (UNWTO 2011). In the preparation of nominations for World Heritage listing, site managers, local communities, national agencies and other stakeholders should document and analyse the experience of women and men in relation to the sites and work together to identify and understand appropriate issues related to gender equality.

Develop tourism investment guidelines that encourage inclusive and equitable development

The development of tourism in and around World Heritage sites should be accompanied by inclusive and equitable economic investment policies (UNESCO 2015). Efforts should also be made to ensure that local communities share equitably in the economic benefits of tourism and that a portion of revenues is re-invested in the management of World Heritage sites and their resilience to climate change. The Community Management of Protected Areas for Conservation (COMPACT) initiative provides a concrete method

and examples for establishing benefit-share programmes for World Heritage sites (Brown and Hay-Edie 2014).

SITE MANAGEMENT AUTHORITIES, INDIGENOUS PEOPLES AND LOCAL COMMUNITIES

Fully incorporate the latest climate science and innovation in adaptation strategies into World Heritage site management planning

World Heritage site management plans should also incorporate climate research in decisions on planning and implementation relating to the sustainability of sites and their OUV. Tourism management and development strategies should be science-based and make use of the latest data on climate change impacts, vulnerability and resilience. There is also an urgent need to incorporate and better understand the climate exposure and sensitivity of OUV in all World Heritage sites and to incorporate arrangements for climate change adaptation and resilience into management strategies, especially at the most vulnerable sites. UNESCO has developed a methodology to guide development of climate change adaptation strategies and plans at World Heritage sites (Perry and Falzon 2014). Experience gained and lessons learned in implementing these guidelines at site level, as well as from innovative strategies for adaptation and resilience-building being developed by States Parties, will be invaluable.

Growing the body of knowledge and practice regarding the links between climate change and site integrity, and effectively disseminating this knowledge to all States Parties is vital. A long-term perspective that takes climate change into account should be applied to all processes of decision making within World Heritage properties, in line with the *Policy for the Integration of a Sustainable Development Perspective into the Processes of the World Heritage Convention* recently adopted by the General Assembly of States Parties to the Convention (UNESCO 2015).

Over at least 2 000 years, the Ifugao people of the Philippines have created a productive landscape of exceptional beauty, but the Rice Terraces of the Philippine Cordilleras are now threatened by climate impacts and cultural change.

Ensure that effective risk reduction, disaster response and preparedness strategies are in place, and are updated regularly utilizing the latest climate science

Climate-related disasters such as severe storms, extreme rainfall events, floods, landslides, droughts and wildfires present a growing threat to the integrity of vulnerable World Heritage sites. Properties should have effective risk-reduction and disaster-response plans with action priorities in place, and update them regularly based on the latest climate change science. UNESCO's resource manual on managing disaster risks provides valuable guidance for managers and management authorities of cultural and natural World Heritage properties to help reduce the risks to these properties from natural and human-induced disasters (UNESCO 2010). Over the long term, management authorities should shift from planning primarily for disaster response and recovery, to strategies that focus on

disaster preparedness, reducing the vulnerability of sites, and enhancing and strengthening the resilience of local communities, in line with the goals of the Paris Agreement (UNFCCC 2015).

For site risk assessment, it is important to evaluate the widest possible range of impacts, including low-probability outcomes with large consequences (IPCC 2014). Site conservation and management strategies should recognize the inherent potential of sites to reduce disaster risk and adapt to climate change through ecosystem services (Osipova *et al.* 2014; Renaud and Sudmeier-Rieux 2013; Temmerman *et al.* 2013). Many World Heritage sites include habitat and ecosystems that serve as natural buffers against climate impacts and other disasters, or play a major role in climate mitigation as carbon stocks and sinks.

Ensure that indigenous peoples and local communities are fully involved at all stages of climate adaptation and tourism development

Utilizing local and traditional knowledge systems for effective adaptation of World Heritage sites is vital in the face of climate change. It is also essential to empower and support local descendent and traditional communities to maintain and preserve what they value, including intangible heritage and subsistence lifestyles (UCSUSA 2014). Indigenous peoples and local communities should be fully involved and their rights recognized in planning for climate adaptation and sustainable tourism development (AAA 2015; UNESCO 2015). This ensures that adaptation strategies contribute to the well-being of the communities, including marginalized groups, and avoids widening existing inequalities (Perry and Falzon 2014).

Around the world, cultural traditions and indigenous knowledge are being lost. These traditions, vitally important in themselves and also often a significant part of the tourism experience, can be damaged, degraded or lost as a result of both tourist contact and climate impacts. It is crucial to arrest this decline and ensure that adaptation and resilience efforts aimed at preserving World Heritage fully incorporate local voices and maximize the use of local and traditional knowledge. UNESCO, through its Local and Indigenous Knowledge Systems (LINKS) programme, has already gained valuable experience in this field that could be leveraged to benefit the management of World Heritage sites.

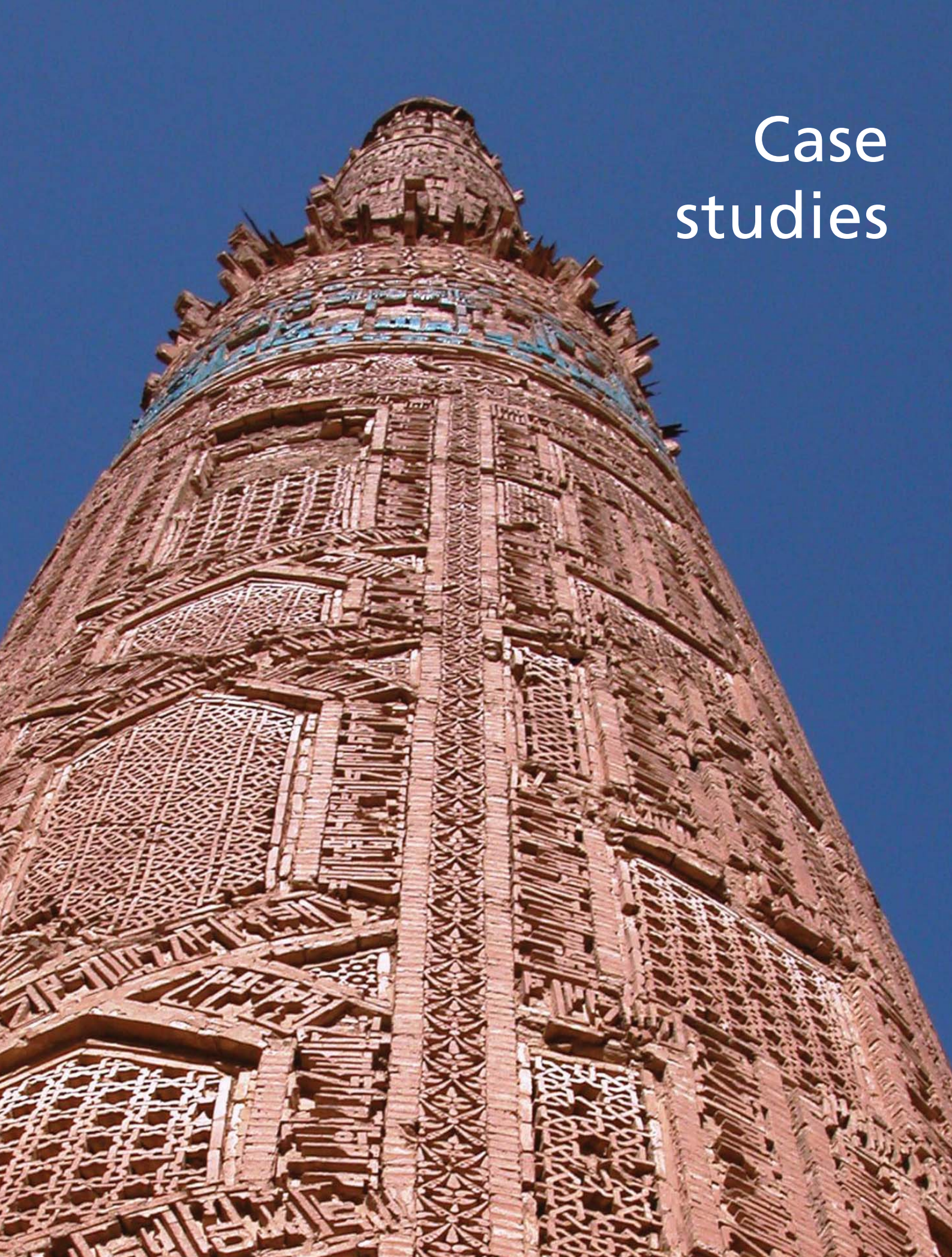
Increase collaboration on site management planning and operations with tourism stakeholders

Where relevant, collaboration with the tourism sector should be a priority for site managers, with attention given to controlling visitor levels and joint activities aimed at conveying accurate information about the site's OUV. Using certification tools such as ISO14001, the Global Sustainable Tourism Criteria and other sustainability standards can strengthen site management planning and operations. Interpretive and accommodation facilities for visitors should be required to adhere to the highest design and sustainability standards that are consistent with, and protect, the site's heritage values.

Establish targeted programmes to raise awareness among tourists, guides, site managers and local communities about the values and protection needs of World Heritage in a changing climate

Tourists visiting World Heritage sites represent an important target audience for awareness raising about climate impacts, adaptation and mitigation. High-quality interpretive materials and programmes can enhance awareness of the risks posed to cultural heritage, wildlife and natural ecosystems from climate change as well as adaptation strategies. Learning about climate change in the locale where its effects are being felt can be a powerful catalyst. Training for tour operators, guides and park rangers can have a magnifying effect. UNESCO's 2009 *Strategy for Action on Climate Change* identified enhancing public education and awareness about climate change, including encouraging the adoption of sustainable behaviours as a key strategic priority (UNESCO 2009). Innovative programmes involving visitor education and ranger training that could serve as models are being developed by the National Park Service in the USA (USNPS Online).

Minaret and Archaeological Remains of Jam, Afghanistan



Case studies

Bwindi Impenetrable National Park, Uganda

Date of inscription: 1994
Criteria: (vii), (x)
Significance: biodiversity hotspot; oasis of tropical forest in an area of dense human population; home to roughly half the world's mountain gorillas

Just under half of the world's remaining endangered 880 mountain gorillas (*Gorilla beringei beringei*) live in southwestern Uganda's Bwindi Impenetrable Forest National Park (IGCC 2011). Gorillas are iconic and their populations here and in their other stronghold in the Virunga Mountains on the borders of Uganda, Rwanda and the Democratic Republic of Congo, have been increasing in recent decades as a result of effective forest management and protection strategies (IGCC 2011). These efforts have been helped by revenue from gorilla tourism in both Rwanda and Uganda.

The Democratic Republic of Congo, Rwanda and Uganda are the only three countries where tourists can currently see mountain gorillas. In Uganda, each visitor that participates in gorilla trekking in Bwindi must pay a fee of US$ 600, helping to make gorilla trekking the highest revenue-generating activity in the country's tourism sector. In 2011, 15 322 permits were issued in Uganda, up 16 per cent from 2010 (MTWH 2012), and estimates put the value of gorilla tourism to Uganda at US$ 20–46 million annually, with the potential to generate US$ 151 million each year (Maekawa *et al.* 2013; Hatfield 2005). However, the gorillas and the economic benefit they represent are likely to come under threat from climate change in the coming years. A changing climate is expected to increase stress and threats to gorillas due to alterations in habitat conditions and perhaps greater vulnerability of the animals to human diseases.

Humans and gorillas

The human population surrounding Bwindi is among the densest in Africa (Kasangaki *et al.* 2012) and the current main threats to the gorillas are habitat degradation, disease transmission from humans and incidental deaths and injuries as a result of poaching for other species (Thorne *et al.* 2013). The human populations around the park are growing, and locals are heavily dependent on natural resources. Illegal incursions

into the park occur for timber cutting, firewood collection, honey gathering and poaching. Charcoal production is a major threat in the region, as is oil and gas development.

Temperatures over most parts of Africa have increased by at least 0.5°C during the last 50–100 years, with minimum temperatures rising faster than maximum ones, and in Uganda increases in seasonal mean temperatures have been reported over the last 50 years. Temperatures in Africa as a whole are expected to rise faster than the global average during the remainder of the 21st century: climate models suggest that for equatorial East Africa, the number of days with temperatures more than 2°C above the 1981–2000 average is likely to increase significantly between 2030 and 2100 (Niang *et al.* 2014; Caffrey *et al.* 2013). Furthermore, while there has been no significant change in annual rainfall for Uganda over the past 60 years, predictions suggest a likely increase in dry season rain and a potential increase in the frequency of extreme rainfall events and floods in the future (Caffrey *et al.* 2013).

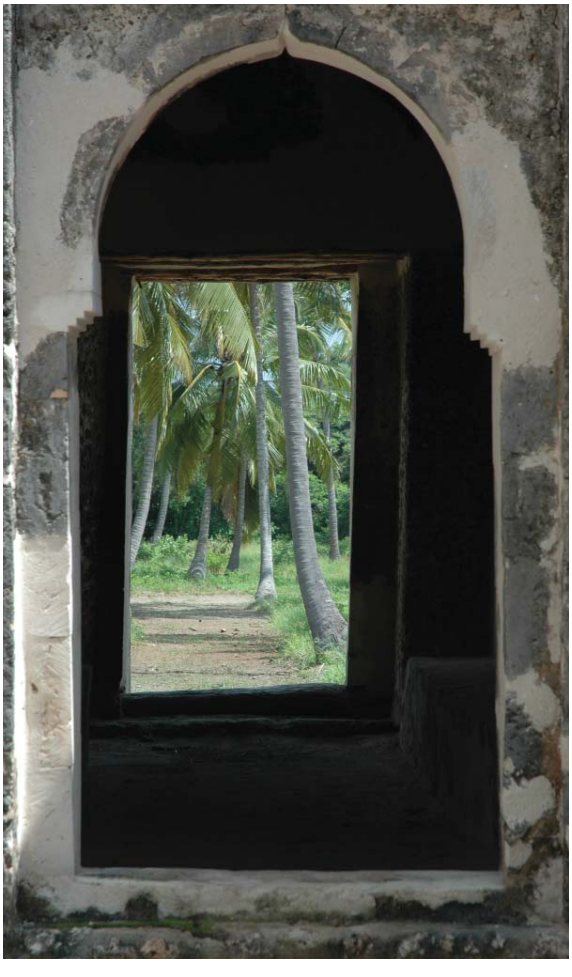
Rising temperatures

Warmer temperatures will bring changes to mountain gorilla habitat and over the longer term are likely to reduce the amount of montane forest available in their current range, with one study suggesting that up to 75 per cent of their current habitat could be lost under severe climatic change (Lehmann *et al.* 2010). Much depends on the ability of gorillas to adapt to new conditions, but no matter how resilient they are, it is highly unlikely that they will be able to expand to new habitat as the protected areas they currently inhabit are surrounded by terraced cultivation and human settlements. Warmer temperatures may also increase human pressures on gorilla habitat, especially if farmers are able to increase the cultivation of crops that were previously limited by the colder conditions on the steep slopes surrounding the park.

In addition to human-caused deforestation, habitat loss and degradation, there is a risk that climate change, together with the expansion of tourism, will increase the probability of disease passing from humans to gorillas. Mountain gorillas are closely related to humans and therefore particularly vulnerable to human diseases. So, whilst tourism has brought many benefits for gorilla conservation and local communities, the proximity of gorilla families that are habituated to tourists increases their risk of exposure to diseases, some of which may be new to them. In Bwindi, habituated gorilla groups have been shown to have a higher incidence of parasites and bacterial infections than non-habituated groups (Kalema-Zikusoka *et al.* 2005). Even without tourism, however, the habitat overlap between gorillas and people around Bwindi, where there is a dense matrix of agriculture and settlements, has already increased the likelihood of gorillas being infected. In one study, in gorillas that harboured strains of the intestinal bacteria *E. coli* that were genetically similar to those in local human populations, 17 per cent had strains that were resistant to one or more locally used antibiotics (Rwego 2008).

Increasing stress for gorillas

The first outbreak of sarcoptic mange, caused by the same mite as scabies in humans, recorded in free-ranging mountain gorillas occurred in a small group of habituated Bwindi gorillas, killing an infant male and severely affecting the juvenile male in the group. There is a strong likelihood that the scabies mites (*Sarcoptes scabiei*) were transferred from the local human population,



Ruins of Kilwa Kisiwani and Ruins of Songo Mnara, United Republic of Tanzania, 1981 (iii)

Tourism in Tanzania is responsible for some 14 per cent of the country's gross domestic product (GDP), and while it mainly centres on wildlife and national parks, several historic and cultural sites are important draws for visitors, too. Among these are the World Heritage listed ruins of two island port cities in the south of the country, Kilwa Kisiwani and Songo Mnara. These cities have been recognized for their role in the growth of Swahili culture, Indian Ocean commerce from mediaeval times, and the arrival of Islam in East Africa. Kilwa Kisiwani was a thriving city from the 9th to 19th centuries AD, with its heyday in the 13th and 14th centuries. Its ruins, many of which remain unexcavated, are largely built of coral and limestone mortar, and it is perhaps best know for the Great Mosque, first built in the 11th century, and the palace of Husuni Kubwa. Coastal flooding and erosion are major threats to Kilwa Kisiwani as sea levels rise due to climate change and the city's vulnerability to damaging storm surges grows. (WTTC 2015; UNESCOa)

Around half the world's mountain gorillas live in Bwindi Impenetrable Forest National Park.

and this particularly small gorilla group was more susceptible to infection because of stress from being tracked and viewed by tourist groups (Kalema-Zikusoka *et al.* 2002). If climate change causes increases in poor health amongst human populations around the park, which, for example, has been suggested as likely for a marginalized and poor local Batwa community (Berang-Ford *et al.* 2012), this could increase the risk of human-to-gorilla transmission of infections. Pioneering efforts, such as those of the NGO Conservation Through Public Health, to increase community heath and awareness in local villages and track gorilla health in order to reduce the risk of disease transmission and outbreaks are important, and several have been successfully under way for a number of years.

The level of stress that gorillas are facing seems to be a significant factor in their susceptibility to human diseases and climate change, and increased tourism is likely to raise stress levels. Nutritional stress can also increase susceptibility to disease in primates, and there is evidence from Uganda's Kibale National Park that climate is already causing changes in food availability. Temperatures in Kibale have increased by 3.5°C over a 25-year period, the rainy season has lengthened and rainfall has increased, leading to some of the most common tree species fruiting increasingly rarely during the 30-year study (Chapman *et al.* 2005).

All indications are that rising temperatures and changes in rainfall regimes will increase stress on gorilla populations, exacerbating the immediate threats posed by habitat degradation, rising tourism and the proximity of rural communities and their expanding populations. Effective ongoing management of Bwindi Impenetrable National Park, its buffer zones and other protected areas as core areas for gorilla conservation is an essential conservation strategy. To support this, it will be vital to maintain the flow of tourism dollars to conservation programmes and local communities. However, tourist impacts must be closely monitored and assessed in the light of climate change, which is expected to increase direct stresses on gorillas and their habitat as well as exacerbate the health risks gorillas face from tourism.

Cape Floral Region Protected Areas, South Africa

Date of inscription: 2004
Criteria: (ix), (x)
Significance: extraordinary diversity and endemism of plant species; evolutionary processes and the unique fynbos ecosystem

South Africa's Cape Floral Kingdom is one of the world's most extraordinary regions for plant biodiversity. A huge magnet for nature tourism, the World Heritage site consists of more than 1 million hectares of protected areas including the Table Mountain and Garden Route National Parks, surrounded by nearly 800 000 hectares of buffer zones. Kirstenbosch National Botanical Garden with its 7 000 garden and wild plant species is also within the World Heritage site (SANBI; UNESCOb).

The region's predominant vegetation is the unique fynbos (fine bush), one of only six floral kingdoms in the world, characterized by fine-leaved vegetation adapted to a Mediterranean-type climate with periodic fires. The region is famous for its plant diversity, including the Proteaceae family that features South Africa's national flower, the king protea (*Protea cynaroides*). In addition to the proteas, the three other main components of fynbos comprise heaths, reed-like Restionaceae and geophytes, and plants with bulbs, corms or tubers, including many beautiful iris, freesia and agapanthus species (UNESCOb). Already under pressure from development and population growth, this extraordinary area, its unique biodiversity and the tourism revenue that supports local livelihoods and helps drive the region's economy are now threatened by the warmer and drier conditions resulting from climate change.

Nearly 3 per cent of South Africa's gross domestic product (GDP) is dependent on tourism and the Cape region, including Cape Town, is the country's largest tourist draw, with one in every ten jobs in the Western Cape related to tourism – more than twice the national average (SSA 2015). Table Mountain, which is within the World Heritage property, is a major destination, with its aerial cableway and spectacular views. The famed Garden Route, in which fynbos is the primary habitat type, is visited by more than a third of all tourists to South Africa (Benfield 2013). Major attractions for visitors to the Cape region include wildflowers and gardens, whale and penguin-watching, and hiking.

The Cape Floral Kingdom is the world's "hottest hotspot" for plant diversity and endemism, and the fynbos is one of five Mediterranean-type biomes in the world, which together contain 20 per cent of the world's known vascular plants (UNESCOb; Lee and Barnard 2015). It has a greater density of species than any of the world's other Mediterranean-type regions and is home to 20 per cent of Africa's flora (9 000 plant species) on less than 0.5 per cent of its land area (UNESCOb).

Changing climate

Climate change has already been recorded in the Western Cape region, with studies suggesting an average warming of 0.1–0.2°C per decade from 1901 to 2006 in the Greater Cape Floristic Region, with rates in the later decades being higher than earlier in the century (Altwegg *et al.* 2014).

For the future, the regional warming trend is expected to continue and the fynbos will get hotter and drier, with an especially marked decrease in winter rainfall. Climate models suggest that by 2070 the fynbos will experience average temperatures over ten months of the year that would have been considered extreme in 1961–1990 (Beaumont *et al.* 2011).

There is also evidence that the incidence of very large fires has increased since the 1990s, and the total average area burned annually has expanded significantly since the 1980s (Kraaij *et al.* 2013a). Fire regimes are expected to continue to change, with greater frequency of fires predicted (Kraaij *et al.* 2013b). One impact of increased fire frequency would be a reduction in the height of the overall vegetation structure, with large proteas being replaced by grasses and fire ephemerals (Lee and Barnard 2015).

Fynbos under pressure

Outside protected areas, the fynbos is already under severe pressure, with approximately 31 per

Lake Malawi National Park, Malawi, 1984 (vii), (ix), (x)

At the southern end of Lake Malawi, one of the world's deepest freshwater bodies, Lake Malawi National Park is a prime, small-scale ecotourism destination. Tourists come for the scuba diving in the clear lake waters and to kayak and hike. The lake has the world's greatest diversity of freshwater fish with over 1 000 species, more than 350 of which are endemic cichlids (Cichlidae). The fish and ecosystems of Lake Malawi are increasingly at risk from a combination of climate change, human population pressure and deforestation. Lake levels have dropped rapidly in recent years, in part due to increased temperatures causing more evaporation. Rainfall is becoming less reliable, dry periods longer and precipitation events more extreme. Water resources for agriculture and energy production are also at risk. (Kumambala and Ervine 2010; UNESCOc)

cent already lost, particularly as a result of the conversion of wildlands to agriculture, urban development and plantation forestry (Huntley and Barnard 2012). Climate modelling suggests that proteas are highly likely to become more restricted in their distribution under future climate scenarios (Midgeley *et al.* 2006), with species in lowland habitats and already restricted ranges likely to be the first to be negatively affected (Hannah *et al.* 2005).

An internationally commercially important endemic plant species of the fynbos is rooibos (*Aspalathus linearis*), which is used to make redbush tea, a herbal drink growing in popularity worldwide, especially in Germany, Japan, the UK and USA. Rooibos was mainly harvested wild but is increasingly being grown commercially in Western Cape Province, where the tea industry provides employment for more than 5 000 people on farms and in factories, and turns over

in excess of ZAR 500 million (*c.* US$ 31 million) annually (SADAFF 2014). The extensive expansion of rooibos cultivation in recent years has been a significant driver of the conversion of natural habitat to small farming operations. Models suggest, however, that the range of both wild and commercial rooibos will shrink significantly as the climate warms and the region dries.

Aside from its incredible plant diversity, the fynbos provides important habitat for many bird species, including six endemic species. Climate projections suggest a significant loss of climatically suitable habitat for these endemic birds, including the protea canary (*Serinus leucopterus*) and Victorin's scrub-warbler (*Bradypterus victorini*), while the Cape rock-jumper (*Chaetops frenatus*) has already been nationally listed with near-threatened status as a consequence of its vulnerability to climate change (Lee and Barnard 2015). Estimates of climate impacts on bird populations that look only at range shifts may underestimate extinction risk. Modelling that takes into account changes in abundance as well as in range generally shows greater population impacts (Huntley *et al.* 2012). Any resulting loss in fynbos species diversity could have major implications, especially if the projected reductions in range and abundance occur for such important pollinators as the orange-breasted sunbird (*Anthobaphes violacea*) and Cape sugarbird (*Promerops cafer*) (Huntley and Barnard 2012).

It is clear that future prospects for this important biodiversity hotspot and tourism centre will be under pressure in an increasingly warm and dry climate. Preservation of the fynbos biome and its extraordinary array of species will depend on careful management of buffer areas, reduced stress from wildland conversion and perhaps increased connectivity of protected areas, even if global mean temperature increase can be kept to 2°C or below.

The Cape Floral Kingdom is the world's "hottest hotspot" for plant diversity and endemism.

Ouadi Qadisha (the Holy Valley) and the Forest of the Cedars of God (Horsh Arz el-Rab), Lebanon

Date of inscription: 1998
Criteria: (iii), (iv)
Significance: early Christian monasteries, cultural landscape of eremitism, sacred cedars, rocky cliffs, caves, terraced fields

Ouadi Qadisha, or the Holy Valley, in northern Lebanon exemplifies the spiritual character of landscapes as places where communities have woven the sacred into the fabric of their natural and built environment. Those who visited or resided in the many monasteries and hermitages of Ouadi Qadisha – some of which date back to the early years of Christianity – sought God within a remote and rugged landscape of soaring cliffs, majestic cedar forests and networks of sheltering natural caves (UNESCOa).

Climate change and tourism development are increasing stress on the traditional livelihoods and ecological systems of Ouadi Qadisha. The valley's sacred cedars, confined to a small remnant stand of approximately 2 hectares known as the Forest of the Cedars of God (Horsh Arz el-Rab), include the oldest and largest cedars known (Beals 1965). The Arz el-Rab forest lies near one of Lebanon's main ski resort towns, Becharre, at the foot of a mountain slope heavily overgrazed and eroded by goats (Shackley 2004). The walled grove includes individual trees of great antiquity – of the 375 or so remaining trees, two are claimed to be over 3 000 years old, and ten to be more than 1 000 years old (ICOMOS 1997), of which perhaps four are older than 1 500 years (Shackley 2004).

Tourism is an important component of the Lebanese economy and, although political instability has caused major drops in visits since a peak in 2009, it still contributed 25 per cent of the country's gross domestic product (GDP) in 2012 (BankMed 2013). In 2000, more than 200 000 tourists visited the grove – 20 per cent of the visitors to Lebanon that year (Shackley 2004).

The cedar of Lebanon (*Cedrus libani*) has carried a spiritual value through the millennia (Hyndman-Rizk 2012; Clark 2011; Moukarzel 2001) and is mentioned some 103 times in the Old and New Testaments, including in Psalm 104:16, which reads "God planted them, and it is He who waters them". For Christians, the trees represent the moral imperative of tending to the gifts of God from generation to generation.

Cedar wood has been prized for its strength and durability for around 5 000 years throughout the Mediterranean (Khuri *et al.* 2000), and the spiritual importance of the cedar trees of Ouadi Qadisha extends well beyond the local communities – as exemplified by its use in the building of temples and sanctuaries throughout the Levant, including the First (Solomon's) and Second Temples in Jerusalem, built in the 10th and 6th centuries BC, respectively (Colette 2009; Loffet 2004). The wood is also synonymous with the great seafaring ambitions of the ancient Phoenicians (Meiggs 1998).

A history of overexploitation

Cedar was so prized as a building material that, according to historical sources from the time of Justinian I (*c.* 482–565), the great cedar forests of Lebanon were already disappearing by the 6th century AD (Mikesell 1969; Giordano 1956). Over the centuries their numbers have continued to decline and, today, approximately only 5 per cent of their original extent survives (Davis *et al.* 1994); the decline is expected to continue due to deforestation and climate change.

Predictions of how the Lebanon cedar will respond to climate change are based on genetic analysis and pollen studies illuminating previous periods of major climate change, such as the transition from the Last Interglacial to Last Glacial period, about 15 000 years ago, as well as the Late Glacial to Early Holocene period, approximately 12 000 years ago (Jeffers and Willis 2014; Hajar *et al.* 2010a, 2010b; Fady *et al.* 2008).

The importance of refugia

Climate change is projected to reduce the *Cedrus libani* populations to only three refugial zones by 2100, due to higher temperatures and water stress from decreased moisture availability in the Mediterranean region (Hajar *et al.* 2010a). While plant communities can adapt to climate change by

Wadi Rum Protected Area, Jordan, 2011 (iii), (v), (vii)

*Wadi Rum, an iconic desert site of narrow gorges, high cliffs, caverns, natural arches and spectacular vistas in southern Jordan, was listed as a World Heritage site for both natural and cultural values. The 30 000-hectare site contains more than 45 000 rock carvings and inscriptions dating back 12 000 years, helping to illuminate the evolution of pastoral societies and the development of the alphabet. Wadi Rum is an important refuge for desert wildlife including threatened sooty falcons (*Falco concolor*), reintroduced Arabian oryx (*Oryx leucoryx*) and the Nubian ibex (*Capra nubiana*), and many of its plants are important sources of food, forage and medicines for the local Bedouin people. Unregulated tourism including off-road driving, illegal campsites, self-guided tours, rock graffiti and the local cultural consequences of more than 300 000 tourists visiting this remote area annually are all taking their toll. Climate change is expected to exacerbate problems in the coming decades. Warmer and drier conditions, with more extreme weather including drought, will increase water stress. Changing climatic conditions are also likely to threaten species dependent on the high mountain habitats of Wadi Rum. There is an urgent need to provide more detailed research on climate change scenarios for Wadi Rum.* (UNESCOb)

migrating to higher altitudes through seed dispersal and gradual replacement, most of the cedar forests of Lebanon are already isolated on or near mountain summits, with nowhere further upslope to go. The Arz el-Rab stand in the Qadisha valley is an exception, being one of the three cedar forests where there is higher-altitude habitat available for potential migration, which makes their protection all the more urgent (Hajar *et al.* 2010a). The cedars of Ouadi Qadisha exemplify the vulnerabilities and loss of resilience that plant communities face with habitat degradation and fragmentation.

There are currently a dozen or more *Cedrus libani* forests in Lebanon – situated at elevations of 1 100–1 925 metres on the western slopes of the Mount Lebanon range, with more than half occupying an area of less than 100 hectares – and they are zones of high biodiversity sheltering other endemic and threatened species (MoE 2015;

Hajar *et al.* 2010a; Talhouk *et al.* 2001a; Khuri *et al.* 2000). The Lebanon cedar is itself listed as vulnerable on the International Union for the Conservation of Nature's (IUCN) Red List (Gardner 2013). The bioclimatic zone of the Arz el-Rab forest is expected to change too, affecting the spatial distribution, species composition and community structure of the cedar forest (Colette 2009). Insect and moth attacks, fuelled by increasing aridity, are already affecting the cedar forests in Tannourine and Shouf, and threatening to spread to the Arz el-Rab sacred cedars (Sattout and Nemer 2008; Talhouk *et al.* 2001a; Khuri and Talhouk 1999).

The cedar of Lebanon is an emblematic species, emblazoned on the flag, currency, and stamps of Lebanon (Hall *et al.* 2011; Talhouk *et al.* 2001b). It is an important element of the Lebanese tourist economy as well as a cultural keystone species, essential to ways of life and religious traditions (Sattout *et al.* 2007; Al Zein *et al.* 2005; Cristancho and Vining 2004).

Ancient Ksour of Ouadane, Chinguetti, Tichitt and Oualata, Mauritania, 1996 (iii), (iv), (v)

*The medieval desert caravan towns (*ksour*) of Mauritania were important trade and cultural centres on the trans-Saharan caravan routes for more than seven centuries. Chinguetti, famous for its square-towered mosque built of un-mortared stone, is the seventh most holy city of Islam and along with the other* ksour *is an important historic attraction for visitors bringing much-needed income to local residents. Tourism in Mauritania is very underdeveloped, and has been hampered in recent years by concerns over travellers' security. Mauritania's* ksour, *once centres of nomadic and Islamic culture in North Africa, are now threatened by the encroaching Sahara. The streets and courtyards of Chinguetti, known for its ancient libraries of Islamic books and manuscripts, are being inundated by sand as dunes migrate into the city. Extreme heat can damage ancient masonry while intense rainstorms threaten earthen architecture and worsen soil erosion problems. Desertification in Africa's Sahel region exacerbates the problem, and its causes are complex, including land-use issues such as overgrazing, deforestation and urbanization, further complicated by climate change. Extended severe droughts and more extreme rainfall events are adding to existing development pressures and resource conflicts.* (UNESCOc; USAID 2012; Brimblecombe *et al.* 2011)

Rock Islands Southern Lagoon, Palau, 2012
(iii), (v), (vii), (ix), (x)

This culturally and biologically rich Western Pacific site extends over more than 100 000 hectares and consists of more than 400 limestone islands, many surrounded by lagoons and coral reefs. The Rock Islands contain the highest concentration of marine lakes anywhere in the world. The site harbours nearly 400 coral species, a great deal of habitat complexity and a high level of species endemism. Although uninhabited today, the remains of abandoned stone villages, including defensive walls and subsistence farming terraces on some of the larger islands, date back some 500–950 years. Ancient rock art, burials and middens provide evidence of occupation over a period of 5 000 years, and archaeologists have been able to demonstrate human use of marine resources over more than 3 000 years. The area holds great cultural significance for modern-day Palauans and its use is regulated through a system of traditional governance. With a population of around 21 000, Palau received 160 000 tourists in 2015 (more than half of them from China), a three-fold increase in just 15 years. Scuba diving and snorkelling are major recreational attractions for visitors and Palau's marine habitats are regarded as among the world's best diving sites. However, pollution associated with rapid tourism infrastructure growth and physical damage to corals from poorly controlled diving and snorkelling are increasing the risk of degradation to Palau's marine habitats. Coral cover worldwide has decreased markedly in recent decades due to a combination of factors including pollution and sedimentation from coastal development, overfishing and disease, but concern is greatest over the impacts of climate change, including in Palau. Rising temperatures in tropical and sub-tropical waters in recent decades have pushed many corals to the limits of their thermal tolerance, and the Southern Lagoon experienced significant coral bleaching in 1998, 2010 and then again in 2015. Worldwide, ocean acidification is occurring as a direct result of seawater absorbing more carbon dioxide from the atmosphere, a change in ocean chemistry that interferes with the ability of corals to build strong calcium carbonate skeletons. Some of the marine lakes of Rock Island Southern Lagoon are naturally acidic, with pH levels close to those projected for the western tropical Pacific open ocean by 2100. Therefore the site provides a unique natural laboratory that may help scientists gain insights about coral reef resilience in the face of global warming and ocean acidification. (UNESCOa; Republic of Palau; Shamberger *et al.* 2014; Poonian *et al.* 2010; Hoegh-Guldberg *et al.* 2007)

Hoi An Ancient Town, Viet Nam, 1999 (ii), (v)
Situated on the banks of the Thu Bon River in Viet Nam's central Quang Nam province, Hoi An is an exceptionally well-preserved example of a Far Eastern trading port that was active from the 15th to the 19th centuries. The old town has more than 1 100 wood-framed buildings, 800 of which date from the 16th and 17th centuries. Tourism is the main economic activity in the city and has surged since its listing as a World Heritage site, with the average number of tourists increasing by 20 per cent year on year from 2003 to 2010. The city is prone to flooding during the annual rainy season, but climate change is expected to worsen conditions considerably in the future. Much of An Hoi is at or no more than 2 metres above sea level, so is vulnerable to sea-level rise, storm surges during typhoons, and coastal erosion. Nearby Cui Dai beach – a major draw for tourists and high-end tourism development – is already losing between 10 and 20 metres of land to erosion annually. Virtually the whole of the An Dinh district, the area of Hoi An with most of the heritage houses, could be flooded annually by 2020 according to a recent UN-Habitat vulnerability assessment. (UN-Habitat 2014)

Shiretoko, Japan, 2005 (ix), (x)
*The extraordinarily productive marine ecosystems of Shiretoko in Hokkaido Province of Japan are directly linked to the formation of the southernmost sea ice in the northern hemisphere. The sea ice drives the production of phytoplankton in the early spring, in turn supporting salmon and trout (Salmonidae), which swim up the rivers, linking the terrestrial habitats and providing food for species including brown bear (*Ursus arctos*) and Blakiston's fish owl (*Bubo blakistoni*). The seasonal drift ice, which also draws thousands of tourists to the park, is now diminishing as a result of climate change. The Shiretoko Peninsula juts into the Sea of Okhotsk and measurements show that sea ice has declined over the last 30 years as a consequence of warming temperatures.* (UNESCOb; Makino and Sakurai 2012; WWF-Japan)

Komodo National Park, Indonesia,1991 (vii), (x)

*The islands of Komodo National Park contain extremely biodiverse ecosystems including mangroves, coral reefs, dry savannah and tropical forest, but they are most famous for the Komodo dragon (*Varanus komodoensis*), the largest living species of lizard and one that exists nowhere else on Earth. More than 60 000 international tourists visited the park in 2013 to see the Komodo dragons, a 20 per cent increase in numbers from 2012. There are not many more than 5 000 lizards in the national park, and, as often happens with such isolated island populations, they are particularly vulnerable to environmental change. Increased rainfall associated with climate change in the very dry Komodo islands could inundate lizard breeding areas and change the vegetation to habitats that are less hospitable to them. Meanwhile, ocean acidification and warming temperatures pose a threat to the islands' wonderful coral reefs and sea-level rise is putting mangrove forests at potential risk. Under these circumstances, tourist numbers and infrastructure development need to be managed with great sensitivity in order to prevent damage to the local ecosystems or additional stress on the Komodo dragons.* (UNESCOc; Nuwer 2012; Holland 2014)

Sagarmatha National Park, Nepal, 1979 (vii)

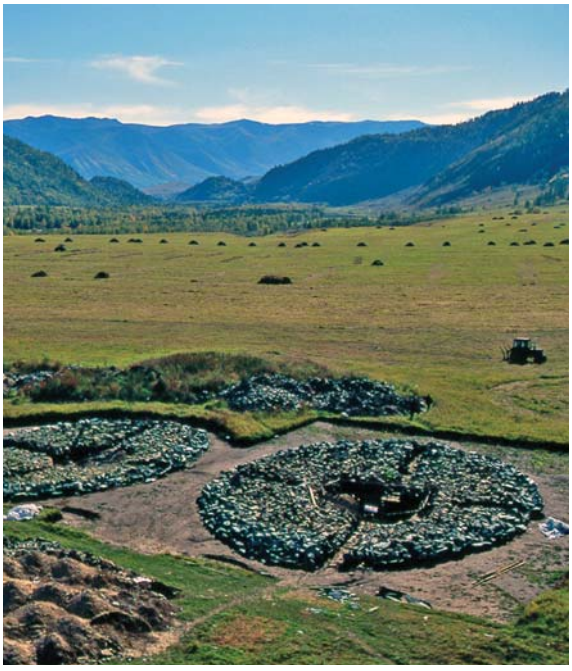
*Encompassing the highest point on Earth – the peak of Mount Everest at 8 848 metres – Sagarmatha National Park is listed as a World Heritage site for the exceptional natural beauty of its landscapes of mountains, glaciers and deep valleys. Sagarmatha is home to a vibrant Sherpa culture that blends traditional agricultural practices with a deep reverence for nature. The park's diverse ecosystems provide sanctuary for the endangered snow leopard (*Panthera uncia*) and red panda (*Ailurus fulgens*), and draw tourists from across the globe for trekking and mountaineering. One third of the people on Earth depend on water that flows from the Himalayas, including from Sagarmatha. This water resource is now being jeopardized, however, as warming temperatures and changes in precipitation are causing Himalayan glaciers to retreat and altering patterns of water run-off. A loss of glaciers can also destabilize surrounding slopes, resulting in catastrophic landslides, and excessive meltwater can cause glacial lake outbreaks or flash floods and erosion. If snow and ice accumulation does not match accelerated glacial melting, water shortages will affect millions of people downstream in the future.* (UNESCOd)

Lagoons of New Caledonia: Reef Diversity and Associated Ecosystems (France), 2008 (vii), (ix), (x)

The World Heritage site includes several protected areas which together cover more than 1.5 million hectares of the most important marine and reef ecosystems of the French islands of New Caledonia in the Western Pacific. New Caledonia's coral reef is one of the three most extensive reef systems in the world and has the greatest diversity of reef structures to be found anywhere. A relatively healthy reef and preserved ecosystem, it has an exceptional diversity and abundance of benthic and pelagic communities, many top predators and large fish as well as globally important populations of dugongs (the second largest world population), turtles and seabirds. New Caledonia receives about 100 000 tourists every year, many of whom come for the diving and extraordinary natural beauty of the lagoon and reef environment. New Caledonia is the world's third biggest source of nickel, and there have been concerns for the health of its marine ecosystems after more than a century of mining operations have resulted in mountainside erosion, sedimentation and pollution in lagoon waters. Climate change is projected to exacerbate the effects of non-climate stresses such as these, as well as overfishing and any impacts associated with future tourism developments. Climate impacts including increased water temperature and ocean acidification are now the biggest threat to coral reefs worldwide. Coral bleaching is mainly triggered by rapid and prolonged increases in water temperatures. This stressful condition for corals results in the colourful symbiotic algae that live in their tissues – and on which they rely for nutrition – being expelled, turning the corals white. Higher ocean temperatures driven by climate change, combined with major El Niño events, caused extended coral bleaching and die-offs around the globe in 1998, 2010 and again in 2015–2016. In New Caledonia, bleaching has so far been restricted to local events – with the notable exception of a 1995–1996 event reported by researchers from France's Institut de recherche pour le développement (IRD). In February 2016, however, marine biologists and oceanographers from the IRD called the alarm on unprecedented mass bleaching on the islands' reefs, and they are currently studying the phenomenon to evaluate its extent and ascertain the causes. (UNESCOe; World Bank; IRD 2016, 2011; NOAA 2015; Gattuso 2014; Pew Charitable Trusts 2015)

Rice Terraces of the Philippine Cordilleras, Philippines, 1995 (iii), (iv), (v)

The indigenous Ifugao people of the Philippine Cordilleras have built and developed their rice terraces over a period of at least 2 000 years. This exceptionally beautiful and important cultural landscape, which draws tourists from all over the world, is highly sensitive to climate change and is already suffering negative effects. Warming temperatures and increases in extreme rainfall events are major problems. More intense rainstorms will increase the instability of the rice terraces built on steep mountain slopes, and cause landslides and erosion. An additional problem is that local rice varieties developed over hundreds of years under stable climatic conditions by the Ifugao are less adaptable to rapid climate change than modern rice strains. Climate change comes on top of cultural perturbations that include the abandonment of rural tradition by young people who are increasingly moving to urban areas. (Manila Observatory; UNESCOf; Katutubo 2015)



East Rennell, Solomon Islands, 1998 (ix)

*Covered in dense tropical forest, Rennell Island is the southernmost of the Solomon Islands in the Western Pacific, and the largest raised coral atoll in the world. The East Rennell World Heritage site comprises 37 000 hectares at the south of the island. The protected area includes the brackish Lake Tegano, the largest lake on any Pacific island. About 1 200 people live in four villages within the property's boundaries and East Rennell was the first World Heritage site to be inscribed with responsibility for its management lying with the traditional and customary owners. East Rennell's outstanding value lies in its undisturbed ecosystems and ecological processes, which make it a natural laboratory for the study of evolution and island biogeography. The integrity of the site as well as its nascent low-impact ecotourism potential are now under threat from commercial logging, the introduction of alien species including the black rat (*Rattus rattus*), and climate change. Warming-induced sea-level*

Golden Mountains of Altai, Russian Federation, 1998 (ix)

Although the Altai Mountains of Russia were originally listed as a World Heritage site for its biodiversity values, the region is equally important for its incredible cultural and archaeological treasures. The Altai Republic is a fast-developing destination for adventure, cultural and eco-tourism, with more than 1.3 million visitors in 2012 and tourist numbers growing annually. The frozen tombs, or kurgans, of the ancient Scythian people are of immense global importance but are now under immediate threat from climate change. The Scythian people, nomadic horsemen and warriors who roamed the steppe from the Black Sea to the Mongolian plains in the 1st millennium BC, left no written or historical record. They are known only from a description by the Greek historian, Herodotus (484–425 BC), and from their tombs. The mounded tombs, which are dotted throughout the more southerly permafrost zones of the Altai Mountains, including within the World Heritage site, were built in such a way that when rain seeped between the rocks, it froze and protected the organic materials within. With their well-preserved artefacts including fabrics, wood, hair and leather, as well as beautiful gold jewellery and objects, the tombs are providing archaeologists with remarkable insights about the Scythians and the evolution of nomadic cultural traditions that are still vibrant in the region today. Warmer temperatures, most markedly in the winter, are melting glaciers in the Altai Mountains and thawing the permafrost where the tombs are located. Urgent efforts are now underway to find a means of protecting the tombs as climate change accelerates. (Brooke 2013; Han 2007)

rise is directly affecting Lake Tegano, raising its water levels and salinity. As a result, coconut and taro crops, vital food staples for the local communities, have been significantly reduced, and houses, tourist lodges and the school have been flooded. (UNESCOg)

Yellowstone National Park, USA

Date of inscription: 1978
Criteria: (vii), (viii), (ix), (x)
Significance: geothermal features; Rocky Mountain landscapes, wildlife, large-scale temperate ecosystem

Created in 1872, Yellowstone was the world's first national park. The park system that began there and has been emulated across the world has famously been called "America's best idea". The iconic Old Faithful geyser, along with more than half of the world's geothermal features – hot springs, mud pots, steam vents and geysers – are located in Yellowstone, and the park's majestic landscapes cover nearly 9 000 square kilometres in the Northern Rocky Mountains (UNESCOa). Visitors come to the park not just for the glorious landscapes, geysers and spectacular hot springs including Grand Prismatic Spring, but also for the opportunity to see herds of bison and other wildlife such as moose, wolves and bears. Yellowstone National Park forms the core of one of the planet's last remaining, mostly intact large-scale temperate ecosystems – the Greater Yellowstone Ecosystem.

Tourists have been coming to Yellowstone since the 1870s, but then, the journey was hard and visitors were few and far between. Nonetheless, more than 5 000 people visited the park in 1883 (NPS 2007). President Theodore Roosevelt, naturalist John Muir and author and Nobel laureate Rudyard Kipling all visited Yellowstone in its early days; today, Yellowstone is the fourth most visited national park in the USA (NPCA), with more than 4 million tourists coming to the park to hike, camp and tour in 2015, a new record (Moore 2015). In 2013, park visitors spent US$ 382 million in communities around the park, supporting 5 300 jobs (NPS 2014).

Scientists now have major concerns about the growing signs of climate change in the park. Temperatures in the Rocky Mountain states of the western USA where Yellowstone sits have risen by 1.17°C since 1895, with the greatest change recorded in the last few decades. Warming in Yellowstone is consistent with this trend and average temperatures in the park have been rising at 0.17°C per decade since 1948 (Chang and Hansen 2015). Average spring and summer temperatures are predicted to increase by 4.0–5.6°C by the end of the century, making hot, dry summers the norm (Romme and Turner 2015; Westerling *et al.* 2011). How big the changes to Yellowstone will be depends partly on the rate of warming – climate models predict that warming during the next 100 years could be equivalent to that which occurred in the 12 000 years since the last ice age. Ann Rodman, a senior park scientist, says that "this is bigger than anything we've ever faced … the potential is out there to affect everything you see when you come to Yellowstone" (NPS 2015).

Warming is already causing winter in the park to become shorter, with less snowfall and snow staying on the ground less often. At the northeast entrance to the park, near Silver Gate, Montana, there are now many more days when temperatures rise above freezing every year than there were during the mid-1980s. Seventy per cent of snow monitoring sites in the park showed a steep decline in snow from 1961 to 2012, and analysis of tree rings shows that there has been a severe decline in levels of Yellowstone snowfall in the early years of the 21st century when compared to the last 800 years (Tercek *et al.* 2015).

Snow totals and the timing of snowmelt affect the rivers and streams of the park. There is often snow cover at the highest elevations in Yellowstone well into June, and the snowmelt controls water availability even in the driest areas. Earlier snowmelt is altering the timing of peak stream flow and, combined with higher summer temperatures in the park, is leading to lower flows and warmer water in the rivers. Reductions in stream flow have been recorded in 89 per cent of monitored streams in the Greater Yellowstone Ecosystem, especially in the summer, and the trend has been particularly pronounced in the Yellowstone River. Stream temperatures have warmed by 1°C during the last 100 years, with the greatest change happening in the first decade of the 21st century. Biologists are predicting a 26 per cent decrease in native

cutthroat trout (*Oncorhynchus clarkii*) because of warmer temperatures (Wenger *et al.* 2011).

The lakes and wetlands of Yellowstone are also changing, with warmer and drier conditions causing them to shrink in some parts of the park. Scientists estimate that 40 per cent of the wetlands in the Greater Yellowstone Ecosystem could be lost under these conditions; at particular risk are seasonal wetlands and the species that depend on them. Chorus frogs (*Pseudacris maculata*) may be under threat since they rely on shallow and ephemeral ponds, while moose (*Alces alces*), trumpeter swans (*Cygnus buccinator*) and sandhill cranes (*Grus canadensis*) are also highly vulnerable to the loss of wetlands (Ray *et al.* 2015).

Yellowstone is known worldwide for its spectacular forest landscapes, and fire is the most important naturally occurring disturbance that shapes and defines these forests. Usually caused by lightning strikes, fire is a natural phenomenon in the forests of the Rocky Mountains and for 10 000 years weather has been the main driver of fires in the forests of Yellowstone (Romme and Turner 2015). Climate change, however, is threatening to radically change the region's fire regime, with rising temperatures heavily influencing Yellowstone's fire season. Across the west, the fire season has lengthened from five months in the 1970s to seven months today, and warmer temperatures are driving an increase in large fires (Climate Central 2012). In Yellowstone, earlier snowmelt, warmer temperatures and a longer fire season are predicted to increase the annual area burned by fires by 600 per cent or more (Peterson and Littell 2014).

More frequent and severe fires are likely to change forest dynamics and transform ecosystems and landscapes in the park (Westerling *et al.* 2011). Long intervals between major fires allow forests to recover and dense tree canopies to develop, but recovery from each fire takes time – it has been estimated that it will take 95 years for the Lodgepole pine (*Pinus contorta latifolia*) forests of Yellowstone to recover the carbon lost in the major fires that burned park-wide in 1988 (Romme and Turner 2015). Over time, more frequent fires are likely to lead to a transition from dense forest to a more open type of woodland, and a different,

The highly calorific pine nuts of the whitebark pine are a critical food source for several Yellowstone species, including the grizzly bear.

less intense fire regime more consistent with what is experienced today in the southwest of the USA may eventually take over. Fire may become limited not so much by temperature and dryness, but by the availability of fuel.

While fire is a major factor for the forest ecosystems of Yellowstone, changes in temperature can also have a direct impact on their distribution. The tree line is likely to move upslope, and species from lower elevations including sagebrush (*Artemisia tridentata* var. *vaseyana*) and juniper (*Juniperus communis* var. *depressa*) communities may well expand their ranges. Meanwhile, suitable habitat for high mountain species such as Engelmann spruce (*Picea engelmannii*) and whitebark pine (*Pinus albicaulis*) is likely to be much reduced and severely restricted (Hansen *et al.* 2015).

Whitebark pine, an iconic mountain tree that can live for more than 1 000 years and is a keystone species of high-elevation ecosystems, is also under severe threat throughout the Greater Yellowstone Ecosystem from climate-driven beetle infestations. The highly calorific pine nuts of the whitebarks are a critical food source for several species of Yellowstone wildlife, including Clark's nutcrackers (*Nucifraga columbiana*), red squirrels (*Tamiasciurus hudsonicus*), and black and grizzly bears (*Ursus americanus* and *Ursus arctos horribilis*) (Funk *et al.* 2014). Recent warming has driven a devastating and historically unprecedented mountain pine beetle (*Dendroctonus ponderosae*) outbreak in the last 15 years, with 79 per cent mortality of mature whitebark pines recorded (Macfarlane *et al.* 2013). Warmer temperatures have allowed more beetles to survive over winter, compromising the trees' defences against beetles and resulting in correspondingly dramatic increases in beetle populations and activity (Logan *et al.* 2010).

The combination of changed fire regimes, more frequent and severe outbreaks of insect pests and a shift to hotter and drier conditions will eventually change the vegetation of Yellowstone. Different tree species from those of today may dominate the forests of tomorrow, and much land that is currently covered by forest may become suitable only for grassland or shrubland ecosystems.

The whitebark pine is under severe threat from beetle infestations driven by a warming climate.

An indicator for wider impacts

Yellowstone can be a useful indicator for climate impacts on large ecosystems. With good habitat connectivity it is well buffered from most other environmental stresses, but it will still change – probably quite extensively – under evolving climatic conditions, perhaps even losing some of its iconic species and landscape characteristics. Climate change impacts will undoubtedly alter the visitor experience though, and if there are more frequent closures for forest fires, reduced potential for fishing or loss of iconic species and landscape features, the tourism economy may suffer (Riginos *et al.* 2015). Yellowstone National Park will continue to draw millions of tourists a year for generations to come, but it can also provide a vital natural laboratory for the study of climate change, as well as an outdoor classroom in which to educate and engage visitors about the problem and its solutions.

Statue of Liberty, USA

Date of inscription: 1984
Criteria: (i), (vi)
Significance: a "masterpiece of the human spirit"; symbol of freedom, democracy and opportunity; technological wonder bringing together art and engineering

The Statue of Liberty is probably the most recognizable statue on the planet and it stands as one of the world's most potent symbols of freedom. Designed by the sculptor Frédéric Bartholdi in collaboration with the engineer Gustave Eiffel, it was given to the USA by France in 1876 in celebration of the centenary of American independence. A masterpiece of colossal statuary and an extraordinary technical feat for its time, the Statue of Liberty consists of a hollow skin of beaten copper laid over an iron framework (UNESCOb). It sits on Liberty Island at the entrance to New York Harbor and has welcomed millions of immigrants and tourists to America from all over the world.

In 2011, the Statue of Liberty National Monument and Ellis Island received 3.7 million visitors, supported 2 200 jobs and brought US$ 174 million into the economies of the states of New York and New Jersey (NPS 2013). Visitor numbers continue to rise, reaching 4.2 million in 2014 (Fickenscher 2015). Although Ellis Island, the famous reception centre that processed nearly 12 million new immigrants between 1892 and 1924, is not part of the World Heritage site, it is closely associated with the statue in the minds of visitors, and is also managed by the US National Park Service. Many tourists visit both sites on the same trip.

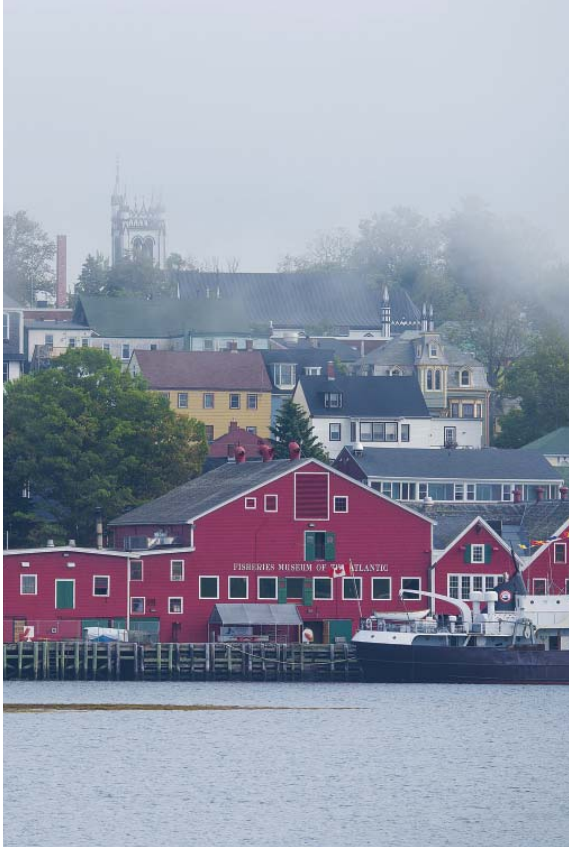
Hurricane Sandy – an unprecedented event

As solid and invulnerable as the Statue of Liberty itself seems, the World Heritage site is actually at considerable risk from some of the impacts of climate change – especially sea-level rise, increased intensity of storms and storm surges. In October 2012, flood waters from Hurricane Sandy inundated 75 per cent of Liberty Island and although the statue and its pedestal were not harmed or flooded, extensive damage was caused to facilities and infrastructure. Together with Ellis Island, the cost of damage from the hurricane exceeded US$ 77 million (Cascone 2015; NPS 2013).

The Statue of Liberty re-opened on 4 July 2013, but Ellis Island remained closed to visitors until October 2015 (NPS). Although no water entered Ellis Island's Main Immigrant Inspection Station, the storm surge from the hurricane destroyed basement electrical heating and cooling systems that support all the inhabited buildings on the island. After the storm, the decision was taken to temporarily relocate more than 1 million temperature- and humidity-sensitive artefacts from Ellis Island's Immigration Museum – including photographs, documents, passports, clothes and immigrants' suitcases – to a climate-controlled facility in Maryland while the island's mechanical systems could be replaced and a new climate control system installed.

New York had never experienced a storm like Hurricane Sandy, and although previous coastal storms have hit the city with more rain and higher winds, the storm surge from Sandy was unprecedented (Holtz *et al.* 2014). Sandy's storm system was 1 600 kilometres wide, three times the size of Hurricane Katrina which devastated New Orleans in 2005, and coincided with a higher tide than normal. Water levels at Battery Park at the south of Manhattan Island reached nearly 4.3 metres, surpassing the previous record of 3 metres set nearly 50 years earlier, and wave heights reached a record 9.91 metres in New York Harbor during the storm (DeConcini and Tompkins 2012). The impacts of this "super-storm" were very significantly exacerbated by local sea-level rise of more than 0.5 metres since records began in the 1850s (Holtz *et al.* 2014). The amplifying effects of rising sea levels mean that storms of lower and lower intensity will cause more storm surge damage in the future. At the same time, rising upper-ocean temperatures in the North Atlantic – temperatures that are projected to continue to rise – are expected to increase the intensity of hurricanes (Sweet *et al.* 2013).

The cost of all the damage caused by Hurricane Sandy was in excess of US$ 60.2 billion and, although this was a once-in-700-year storm, global warming and sea-level rise are likely to drastically increase the likelihood of this kind of



Old Town Lunenburg, Canada, 1995 (iv), (v)
Lunenburg on the southern coast of Nova Scotia is the best example of a planned British colonial settlement townscape in North America. Since its establishment in 1753, Lunenburg has been dependent on its waterfront and the North Atlantic for its main industries of fishing, shipping, ocean commerce and now tourism. More than 1.8 million tourists visit Nova Scotia annually and tourism revenue on the south coast exceeds CAD $ 160 million (c. US$ 115 million) a year, with Lunenburg being one of the top destinations. Rising seas threaten to inundate some coastal land permanently, and higher water levels will also result in more damage from storm surges and flooding in parts of the Old Town that have not previously been affected. Many buildings and roads are vulnerable, and among those most at risk is one of Lunenburg's major tourist attractions, the Fisheries Museum of the Atlantic, housed in a complex of historic buildings on the waterfront. (Forbes and Wightman 2013; UNESCOc)

storm and its impacts in the future (Sweet *et al.* 2013). Meanwhile, sea levels along the Atlantic coast from Cape Hatteras, North Carolina to Maine, including New York, have been rising at four times the rate of the rest of the US coast during the last 20 years (Sallenger *et al.* 2012).

Hurricane Sandy closed Liberty Island for nine months, seriously damaging or destroying much of the infrastructure on the island including electrical, water, sewage, security and telephone systems (NPS 2013). Repairs to the island after Sandy included replacing an 84-metre dock that required 12 800 square metres of lumber, 53 000 new paving blocks to rebuild the walkways, more than 600 metres of granite edging and more than 130 metres of railings. The storm also destroyed visitor security screening facilities at Battery Park in Manhattan and Liberty State Park in New Jersey, forcing complete rebuilds (NPS 2013). To increase resilience to future storms, electrical systems have been raised as much as 6 metres above sea level on both Liberty and Ellis Islands (Holtz *et al.* 2014). The Statue of Liberty was recently re-fitted with an energy-efficient light-emitting diode (LED) lighting system located above ground and flood levels, rather than in the lighting pits that were flooded in the 2012 storm. All in all, US$ 100 million will have been spent on restoration projects once Hurricane Sandy recovery is complete.

Lessons learned

A 2015 vulnerability analysis carried out by the US National Park Service on its coastal properties concluded that 100 per cent of the assets at Liberty National Monument are at "high exposure" risk from sea-level rise due to the extremely low elevation of the island and its vulnerability to storms. The assets at risk on

Mesa Verde National Park, USA, 1978 (iii)
Mesa Verde National Park preserves the cultural heritage of many of today's Native American tribes, including the Hopi, Laguna and Zuni. Once-nomadic Ancestral Puebloans began settling here in the 6th century, 1 000 years before Europeans began exploring North America. They built their homes on the high plateau of Mesa Verde and then in the sheltered alcoves of the canyon walls and overhanging cliffs, before abandoning the region and moving south, perhaps because of climatic changes, to present-day Arizona and New Mexico. Temperatures are rising in Mesa Verde and it has been warmer since 1950 than at any time in the past 600 years. Annual rainfall is declining and so too is stream flow in the park. As in much of the western USA, hotter drier conditions are leading to a longer wildfire season and greater number of large wildfires. Mesa Verde's 4 500 archaeological sites are under severe threat of irreversible damage both from the increasing wildfires and from the flash floods and erosion that often follow. The vulnerability of Mesa Verde's cultural assets to climate change could have a negative effect on tourism in the park, which attracts about 500 000 visitors a year contributing about US$ 47 million to the local economy. Damage to archaeological sites and the iconic cliff dwellings could change this, as could more frequent park closures due to large wildfires. (Holtz et al. *2014)*

Liberty and Ellis Islands, including the Statue of Liberty itself, are valued at more than US$ 1.5 billion (Peek *et al.* 2015), but the intangible cost of future damage to this international symbol of freedom and democracy is incalculable. Hurricane Sandy's damage to the infrastructure of the Statue of Liberty World Heritage site was extensive and tourism to one of the most popular attractions in the USA had to close for many months, but the lessons learned from its recovery can provide a model for other vulnerable coastal sites.

Port, Fortresses and Group of Monuments, Cartagena, Colombia

Date of Inscription: 1984
Criteria: (iv), (vi)
Significance: colonial buildings and military architecture of the 16th, 17th and 18th centuries; history of world exploration and maritime trade

Founded in 1533, Cartagena de Indias has one of the most extensive and complete complexes of military fortifications in South America. Strategically located on the northern and Caribbean coast of Colombia, the city played a central role in the struggles between European powers competing for control of the "New World" in the 16th, 17th and 18th centuries. The city was a central hub for maritime trade in the West Indies and offers a rich history and legacy of colonial architecture to its visitors. Today, nearly 500 years after the Spanish conquest of Colombia's Caribbean coast, Cartagena is enjoying a tourist boom that is bringing jobs and economic revitalization to the region. Rapid sea-level rise and coastal flooding, however, are putting these developments at risk.

Inside thick defensive walls, the historic centre of Cartagena is one of Colombia's top tourist destinations, packed with squares, museums, churches and ornate colonial buildings including the Palace of the Inquisition and the cathedral. The city received World Heritage status for its array of 16–18th century military fortifications, built to protect Spanish colonial and trade interests in the region. As a result of a major effort, begun in 2002, to increase security in Colombia and re-brand the country's image as a desirable tourist destination, this beautiful colonial city of 1.4 million inhabitants now attracts more than 500 000 tourists a year, more than half of them arriving on cruise ships (Dubov 2013). Cartagena's airport handles over 3 million passengers a year, a number that grew by at least 20 per cent annually between 2008 and 2012 (Maslen 2013), and more than 30 per cent of Cartagena's jobs are now in the tourism industry. Beyond tourism, the city's modern port handles 60 per cent of the country's maritime trade and Cartagena as a whole contributes 6 per cent of Colombia's gross domestic product (GDP) (Zamora-Bornachera 2014).

Because of its low-lying coastal situation, Cartagena is one of the coastal cities in the Caribbean most vulnerable to sea-level rise (Reguero *et al.* 2015).

The average sea-level rise for the Caribbean basin was approximately 2.5 millimetres a year from 1993 to 2010, consistent with global trends. The rate of rise at Cartagena, however, has been more than twice the Caribbean average due to local factors, especially land subsidence, probably caused by extensive urbanization, and has averaged 5.3 millimetres a year over the same period (Torres and Simplis 2013). Increased frequency and intensity of storms and inadequate urban drainage and storm-water systems amplify the risks from climate change (Adams and Castro 2013).

Climate models suggest that a 2°C rise in temperature would lead to a further increase in sea level of as much as 60 centimetres by 2040. This would result in more than 25 per cent of the population and residential properties in the city being affected by flooding during high tides. More than 30 per cent of Cartagena's population live at or below the poverty level, and the lowest-income neighbourhoods, including those located around the Ciénaga de La Virgen marshland and on the island of Tierra Bomba, are most vulnerable to increased flooding (Zamora-Bornachera 2014).

Through all of its nearly 500-year history, Cartagena has been inextricably tied to the sea. The city now faces its greatest modern challenge as a result of accelerated sea-level rise, coastal flooding and shoreline erosion. Its sprawling squatter settlements and poorest neighbourhoods are on the front-line of climate change and the historic colonial centre that attracts tourists, creates jobs and keeps the economy growing is under threat.

The walls, parapets, forts and buildings that comprise the World Heritage site are subject to varying degrees of risk. For example, a recent UNESCO assessment identified the Fort of San Fernando as being affected by erosion, sedimentation and waves but that it had not yet been seriously affected. In contrast, the Fort of San Jose has already been significantly damaged and undermined by waves and erosion, putting its future in question (UNESCO 2014).

In response to the threat to its economy, infrastructure, cultural heritage and neighbourhoods, Cartagena is the first city in Colombia, and one of the first in Latin America,

Sea-level rise and greater storm intensity are threatening several poor neighbourhoods on the low-lying coast and jeopardizing the tourist boom that is bringing jobs and economic revitalization to the Cartagena region.

Coro and its Port, Venezuela, 1993 (iv), (v)

One of Venezuela's top tourist destinations, the city of Coro dates from the earliest days of Spanish colonization, having been founded in 1527. Coro and its port, La Vela, are unique on the Caribbean coast for the use, since the early 16th century, of unfired earth to build structures including churches, civic buildings and homes. Coro was put on the List of World Heritage in Danger in 2005 as a result of significant damage caused by unusually intense rain and storms in 2004 and 2005. The Central America and Caribbean region has been identified as one of the tropical parts of the world most responsive to climate change, and has experienced a marked increase in extreme weather events including droughts, storms and floods over the last 30 years. Increased intensity of periodic rainstorms presents the primary threat to the historic buildings of Coro and La Vela, causing roof leaks, erosion of mud-roof mortar, structural cracking, damp walls, wall collapses and landslides. Major strides in addressing these problems have recently been made through collaborative efforts involving the state, community and traditional artisans. There are positive signs that proactive adaptation strategies can help maintain this important heritage and tourism resource under changing climate conditions. (UNESCOa)

to develop a comprehensive climate resilience and adaptation strategy and to provide the analysis, research and recommendations necessary to integrate climate vulnerability into all municipal planning processes (Adams and Castro 2013). Plan 4C provides a road-map for planning climate-compatible development so that the city is prepared for climate impacts by 2040 and is able to continue to boost economic development – including industry, maritime trade and tourism – while maintaining its historic buildings and monuments in the face of accelerating climate change (Zamora-Bornachera 2014).

Plan 4C's vision states: "by the year 2040, the historic heritage of Cartagena de Indias will be resilient to climate change. This will be made possible by carrying out actions within the framework of climate compatible development, maintaining its value as a World Heritage City and a Cultural Interest Asset for the people of Cartagena and visitors" (OMCI *et al.* 2014). The plan outlines key measures needed to achieve this vision, among which is the protection of assets of cultural interest, revitalization of public spaces, development of sustainable transport, promotion of energy efficiency, and adoption of land management and financial instruments. As outlined in the plan, historic heritage protection entails both mitigation and adaptation strategies. The adaptation strategies include the development of a work plan for cultural asset protection to prevent flooding in the historic centre, as well as for the restoration and preservation of buildings.

Galápagos Islands, Ecuador

Date of inscription: 1978
Criteria: (vii), (viii), (ix), (x)
Significance: biological diversity and marine ecosystems; instrumental in the development of Charles Darwin's theory of natural selection; ongoing evolutionary, geological and geomorphological processes

A thousand kilometres off the coast of Ecuador, at the confluence of three Pacific currents, lie the Galápagos Islands, an archipelago of 18 large islands, three smaller ones and more than 100 islets and rocks that are home to a remarkable diversity of species (UNESCOb).

First colonized by Ecuador in 1832 and most famously visited by Charles Darwin in 1835, the islands are known worldwide for the role their species, particularly the finches (Fringillidae), played in helping Darwin form his theory of evolution by natural selection. The islands are now one of the world's hotspots for wildlife tourism and are struggling to balance increasing visitor numbers and infrastructure development with conservation imperatives.

The first cruise ship arrived in the islands in 1969 and in 1970 there were fewer than 5 000 cruise visitors, but by 1999 that number had climbed to 66 000 (NOAA). Today, three airports on the islands also serve an average of six flights a day. The original management plan of 1973 established a maximum of 12 000 visitors per year, but that has been constantly revised upwards and, in 2013, 205 000 people visited the islands (Parque Nacional Galápagos). Galápagos tourism generates US$ 418 million annually, of which US$ 61 million enters the local economy, fully 51 per cent of the islands' revenue (Galápagos Conservancy a). The resident population of the islands was around 4 000 in the 1970s, but demand for visitor services has been a big driver of rapid growth – the population doubled between 1991 and 2005 and today it stands at around 25 000 people (Galápagos Conservancy b).

Charles Darwin described the Galápagos as "a little world within itself" and marvelled at the variety of species. He said, "I never dreamed that islands, about fifty or sixty miles [80–96 kilometres] apart, and most of them in sight of each other,

formed of precisely the same rocks, placed under a quite similar climate, rising to a nearly equal height, would have been differently tenanted" (Galápagos Conservancy b).

The Galápagos terrestrial species demonstrate an unusually high level of endemism: of 500 native vascular plants, 180 are found nowhere else on Earth. The surrounding marine environment is similarly rich, with the 2 909 known species having greater than 18 per cent endemism (UNESCOb). Due to their extreme isolation, many unusual species have evolved on the islands, including giant tortoises (*Chelonoidis nigra*), marine iguanas (*Amblyrhynchus cristatus*) and flightless cormorants (*Phalacrocorax harrisi*). The islands are also famous for the many variations and subspecies, including land snails (Bulimulinae) and birds including mockingbirds (Mimidae) and Darwin's finches (Thraupidae), which have evolved, and continue to do so today, in isolation from each other on the many islands with their range of habitats.

The main threats to the biodiversity of the Galápagos Islands in recent decades have been tourism and population growth, the introduction of alien and invasive species, and illegal fishing (UNESCOb). Now climate change is also having an impact, and represents a new threat that will exacerbate some of these problems and bring new issues to the fore. Climate concerns relate to impacts resulting from global trends of rising sea levels, warming oceans and atmosphere, ocean acidification and changes in rainfall and extreme events, all of which can have negative consequences for the islands' ecosystems.

Of particular concern is how the El Niño Southern Oscillation (ENSO), which dominates climate variability on an inter-annual basis in the Galápagos, may change as a result of global warming. Since 1880, El Niño events have occurred every two to seven years or so, warming the waters around the islands and bringing much wetter years to the archipelago (Sachs and Ladd 2011).

Giant tortoises and marine iguanas are among the 18 per cent of Galápagos species that are endemic, as well as being considered top attractions by tourists visiting the islands.

Particularly severe El Niño events, such as those experienced in 1982–1983 and 1997–1998, can have devastating impacts on Galápagos species as food supplies are disrupted. The severe weakening of the Equatorial Undercurrent associated with El Niño affects the entire food web, with warmer waters reducing the upwelling of nutrients that usually characterizes the cold waters around the Galápagos, resulting in a reduction in phytoplankton availability and causing small fish and invertebrates to migrate away, as well as reducing the growth of algae on which many species rely. As a consequence, the extreme El Niño events of the 1980s and 1990s resulted in declines of up to 90 per cent in marine iguana populations, 75 per cent in Galápagos penguins (*Spheniscus mendiculus*) and 50 per cent declines in sea lions (*Zalophus californianus wollebacki*) and flightless cormorants (Larrea and DiCarlo 2011).

Surveys of tourists to the Galápagos have identified which species are most important to visitors to the islands. All seven of the most important species, those for which more than half of the visitors said they might not have visited the Galápagos if they were not there, including giant tortoises, marine iguanas, sea lions and penguins, are deemed by scientists to be likely to decline in a warming climate (Quirroga *et al.* 2011).

A recent review of worldwide environmental threats found that Galápagos penguins have the highest vulnerability to climate variability of all penguin species (Trathan *et al.* 2015). The penguins depend on the hugely productive cool water upwellings that bring nutrients and fish – such as Peruvian anchoveta (*Engraulis ringens)* and Pacific sardines (*Sardinops sagax caerulea*) – to the waters off the coast of the Galápagos Islands and make the Humboldt Current the most productive fishery in the world. But with warmer waters in El Niño years disrupting the upwelling and cutting off the supply of fish, Galápagos penguin populations are only 25 per cent of what they were in the 1970s, recovering only slowly from the devastating mortality caused by the major events of 1982–1983 and 1997–1998 (Quillfeldt and Masello 2013). Evidence already exists that El Niño events increased in intensity during the 20th century, and some climate models suggest that the frequency of super El Niño events could double over the next 200 years (Climate Central 2014).

Coral reefs are also affected by each El Niño event, with bleaching occurring due to the warm waters. The reefs can usually recover from these bleaching events, but, with increased overall temperatures and acidification due to climate change, they may be less resilient in the future, since the intervals between bleaching events are becoming shorter and ocean acidification reduces the capacity of corals to build their calcium-carbonate-based skeletons.

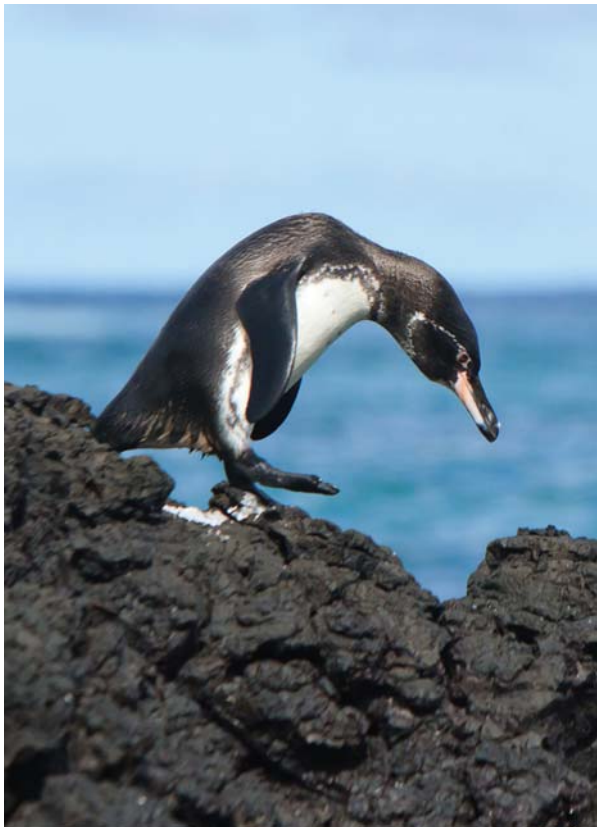
On land, the increased rainfall of El Niño years affects the arid zones more than the humid highlands. There is a massive increase in plant growth, including herbaceous undergrowth, vines and creepers, and there is greater mortality of tall cactuses such as prickly pear (*Opuntia echios*), jasminocerus (*Jasminocerus thouarsii*) and palo santo (holy wood) trees (*Bursera graveolens*), due to the plants toppling over as a result of being water logged or smothered in creepers (Trueman *et al.* 2011).

Wet soils and increased vegetation have reduced the temperature of soils, causing turtle nests to fail, and introduced fire ants (*Solenopsis*) have been seen to kill hatchlings in wet El Niño years (Trueman *et al.* 2011). Giant tortoises have also been observed falling down ravines or drowning in floods during extreme weather. Endemic land birds, too, appear to suffer in El Niño years – although breeding birds tend to respond positively to wet years, this appears to be offset by the impact of introduced diseases and parasites, with avian pox and the parasitic fly *Philornis downsii* being of particular concern (Dvorak *et al.* 2012; Trueman *et al.* 2011). Probably introduced in the 1890s, avian pox increased dangerously in seven species of finch between 2000 and 2009 (Zylberberg *et al.* 2012).

New, introduced and invasive alien species are better able to establish themselves in wet El Niño years. Plants that have spread, especially in inhabited areas, since the 1982–1983 and 1997–1998 El Niños include arrowleaf or common sida (*Sida rhombifolia*), lantana (*Lantana camara*) and Mysore raspberry (*Rubus niveus*). A population of an introduced bird, the smooth-billed ani (*Crotophaga ani*), exploded on Santa Cruz Island after the 1982–1983 event and spread to other islands. The first known amphibians in the Galápagos were introduced tree frogs (*Scinax quinquefasciata*), which established a resident population during the 1997–1998 El Niño and remain a threat to the islands' invertebrate diversity (Trueman *et al.* 2011).

Already under pressure from tourism development, population growth and the impacts of introduced species, the native wildlife and ecosystems of the Galápagos will be significantly affected by changes in the climate. The key factor looks likely to be how changes in El Niño and other cyclical events are manifest under global warming and how ocean currents and productivity respond.

Galápagos penguin populations suffer very considerable declines during El Niño events.



Huascarán National Park, Peru

Date of inscription: 1985
Criteria: (vii), (viii)
Significance: tropical mountain landscapes; glaciers and lakes; biodiversity

Huascarán National Park is a place of exceptional beauty. Situated in the Cordillera Blanca – the world's highest tropical mountain range – the park features Huascarán, the highest peak in Peru rising to 6 768 metres, and some of the most dramatic mountain landscapes on the planet. Stretching over 340 000 hectares, the park contains almost 660 glaciers and 300 lagoons (SERNANP).

The park is also known for the diversity of its flora and fauna. It is recognized as an Important Bird Area and is home to 135 bird species (BirdLife International). The diverse flora includes such outstanding elements as relic forests of endangered *Puya raimondii* (IUCN) which, also known as the queen of the Andes, is the largest species of bromeliad, reaching 3 metres tall with flower spikes up to 9–10 metres – the largest inflorescence in the world (Parkswatch 2005).

Huascarán National Park is a popular destination among local and foreign tourists, with visitor numbers increasing steadily from 112 000 in 2010 to more than 180 000 in 2014 (SERNANP 2015). Mountaineers come from all over the world to confront the challenges of its peaks and it is a popular destination for bird watching (SERNANP), but the majority come to admire the beauty of the Cordillera Blanca and its turquoise lagoons.

However, the social and economic importance of the area lies not only in its value as a tourism destination, as the glacier run-off constitutes one of the main water sources for many local communities, as well as for hydropower (Vuille *et al.* 2008).

Recent climate change is having major impacts on the Cordillera Blanca. Since the 1930s, the area's glaciers have shrunk by 30 per cent (Schauwecker *et al.* 2014) and, in the 30 years since their first comprehensive inventory, 151 smaller glaciers of less than 1 square kilometre have disappeared (Portocarrero 2011). Observed

trends also include a rise in the elevation of glaciers and an increase in the number of glaciers due to the disintegration of larger ice bodies (Racoviteanu *et al.* 2008). Furthermore, studies of temperature changes in the Cordillera Blanca report an increase of 0.39°C per decade between 1951 and 1999, with some slowdown in the rate of temperature increase in the more recent years (Schauwecker *et al.* 2014; Mark and Seltzer 2005).

There are several concerns associated with glacier retreat. One of them is its impacts on water availability – the ongoing retreat of the glaciers, coupled with increasing population, makes the Andean communities more and more vulnerable to declining water resources (Baraer *et al.* 2012). In addition, melting of the ice exposes rocks rich in heavy metals, including lead, arsenic and cadmium, and meltwater run-off now carries these toxic metals into the rivers, significantly affecting water and soil quality (Collyns 2015). Huascarán National Park is also being affected by other threats, including overgrazing which leads to soil degradation (SERNANP 2013). The combination of these factors could lead to serious social conflicts in the area. Glacier retreat is also increasing the risk of natural disasters, including avalanches and glacier-lake outburst floods

Atlantic Forest South-East Reserves, Brazil, 1999 (vii), (ix), (x)

*Once a lush forest covering about 134 million hectares, the Brazilian Atlantic Forest has now been reduced to less than 15 per cent of its original area and what remains is highly fragmented. The Atlantic Forest is a biodiversity hotspot, with hundreds of species found nowhere else on Earth, many of which are considered threatened or endangered, including the golden lion tamarin (*Leontopithecus rosalia*). Characterized by an environmental gradient from mountain slopes covered in dense forest to wetlands, as well as a variety of other habitats, the Atlantic Forest's proximity to the coast has been the main driver of its destruction. Urban development, land-use change, and illegal logging and occupation are key factors that threaten these ecosystems. Climate change, particularly in the form of sea-level rise and extreme weather, has more recently become a threat, with changing environmental conditions, landslides and floods following torrential rains, and droughts leading to habitat degradation and loss. Landslides have also caused loss of life in the encroaching urban dwellings all around the forest. Tourism, especially eco-tourism, has brought financial resources and awareness for conservation, and several non-governmental organizations have been working on conservation and adaptation initiatives, including restoration of degraded forests and other habitats to reduce the impacts of various threats. Improved connectivity between forest fragments will be a vital adaptive strategy as the climate continues to change.* (GIZ; TNC; UNESCOc)

Rapa Nui National Park (Easter Island), Chile, 1995 (i), (iii), (v)

Rapa Nui, or Easter Island, is famed for its iconic carved moai *statues and ceremonial* ahu *platforms on which many of them stand, all dating back to around 1250–1500 AD. In the southeast Pacific Ocean more than 3 500 kilometres off the coast of Chile, Rapa Nui is the most remote inhabited island on Earth. With a resident population of approximately 5 000 people, the island's economy is dependent on tourism and some 60 000 people visit every year. During the summer months the island's population doubles, with an average of 5 000 tourists daily. The primary impacts of climate change on Rapa Nui are projected to be water shortages due to reduced summer rainfall, sea-level rise, coastal inundation and erosion. The majority of the* ahu *and* moai *are located directly on the coast and significant coastal erosion impacts are already being recorded at several important archaeological sites. With climate change, the greater wave heights and increased energy of the waves hitting the* ahu's

vertical basalt slab walls, the ahu *are expected to undergo worsening damage and the* moai *that sit on top of them could topple. Four of the sites most important for tourism – Tongariki, Hanga Roa, Tahai and Anakena – have recently been identified as among the most seriously threatened by wave damage.* (UNESCOd; J. Downes, pers. comm.; Quilliam *et al.* 2014)

(GLOFs), with potentially disastrous impacts on nearby communities (Portocarrero 2011).

The glacier retreat is also affecting tourism in Huascarán National Park. The Pastoruri Glacier, one of the main attractions of the park, lost 40 per cent of its surface area between 1995 and 2005 and, if the trend continues, may disappear altogether very soon (La Republica 2007). The Cátac District, in Recuay Province, has been suffering from a significant drop in the income they receive from tourism as the number of visitors has fallen to around a third of the 100 000 annual visitors that came in the 1990s (Collyns 2015). As a result, many of the district's inhabitants have left for larger cities in search of jobs (Rumbos de Sol y Piedra 2012).

But even the disappearance of a glacier, despite being an irreversible loss, can create opportunities, and the community of Cátac has been working together with the Servicio de Áreas Naturales Protegidas por el Estado (SERNANP) and the Ministry of Tourism on the creation of a climate change trail (*La ruta del cambio climático*), which is designed to provide the visitors with scientific information on glacier retreat and help raise awareness of the effects of climate change. The trail and its associated infrastructure, including a lookout point from which the tourists can observe the current state of the dwindling glacier, were completed in 2014 (El Comercio 2014).

With current trends projected to continue, other glaciers in Huascarán National Park may share the fate of Pastoruri. As the world keeps walking the "trail of climate change", will this magnificent tropical mountain range remain a Cordillera Blanca?

Ilulissat Icefjord (Greenland), Denmark

Date of inscription: 2004
Criteria: (vii), (viii)
Significance: geologic phenomenon that helps scientists understand the last ice age and climate change; wild and scenic combination of rock ice and sea; fast-moving glacier

Ilulissat Icefjord, 400 kilometres north of the Arctic Circle in west Greenland, may be one of the few places in the world where climate change is helping to drive tourism. It is where the massive Sermeq Kujalleq or Jakobshavn Glacier meets the sea in the Disko Bay. The fjord, which is usually frozen over in the winter, offers summer visitors an incredible opportunity to see and hear the spectacular cracking and calving of ice into the ocean. The glacier has been studied by scientists for more than 150 years and has played a major part in the scientific understanding of glaciology (UNESCOa). One of the fastest-moving glaciers in the world, Jakobshavn has recently accelerated significantly and the ice sheet is thinning (NASA 2014).

The Antarctic and Greenland ice sheets hold enough water to raise global sea levels by approximately 65 metres if they melt completely (Rahmstorf 2010). Much of the uncertainty regarding future rates of sea-level rise is linked to current efforts to fully understand the mechanics of glaciers. The recently increased flow rate of Jakobshavn Glacier appears to be associated with both oceanic and atmospheric warming (Alley *et al.* 2005). The Arctic as a whole is warming twice as fast as the global average, with winters warming most dramatically. Higher temperatures mean that summer sea ice has declined to the smallest extent recorded during the satellite era, permafrost is thawing throughout the Arctic (NRC 2015) and the region's glaciers are shrinking too.

A last-chance destination

For such a remote place, Greenland and Ilulissat attract a significant number of tourists – some 60 000 a year – approximately half of them arriving on cruise ships (Stromberg 2011). The number of cruise ships travelling to Greenland increased from 13 in 2003 to 39 in 2008, and climate change impacts are being used to promote

the island as a destination to be seen before it disappears (Hall and Saarinen 2010). Greenland has taken full advantage of climate change promotional opportunities, as reflected in the government's tourism website, Greenland.com: "visiting the Ilulissat Icefjord is not only about seeing a large calving glacier or melting icebergs before it's too late. It is a unique opportunity to be active in the climate change conversation here at 'ground zero' and to let your experiences in Greenland inspire your life back home".

The main outlet to the sea for Greenland's inland ice, Jakobshaven Glacier drains 6.5 per cent of the 1.7 million square kilometres of the Greenland ice sheet and produces 10 per cent of its icebergs – some 25–50 cubic kilometres annually (Weidick and Bennike 2007).

The recent dramatic increase in the rate of flow of Jakobshavn Glacier may have been caused by the loss of its floating ice tongue, the penetration of surface meltwater to the base of the glacier, the wider and deeper geology at the current terminus of the glacier, higher ocean temperatures, or a combination of all these (Joughin *et al.* 2014; Holland *et al.* 2008; Alley *et al.* 2005). Jakobshavn Glacier retreated 40 kilometres between 1850 and 2010, but the rate of retreat and thinning has increased markedly and it is now losing more mass than it is gaining each year (NASA 2015). Already a fast-moving glacier, Jakobshavn's speed reached a peak of 17 kilometres over the year in 2012, three times the annual rate of the 1990s (Joughin *et al.* 2014).

Ilulissat Icefjord was listed under the World Heritage Convention for its unique, wild and scenic landscape, for its global importance as a geological feature, and its role in scientific understanding of the last ice age and ice sheet dynamics. The site is also important, however, for its archaeological

The faster rate at which Arctic temperatures are rising relative to the rest of the world makes Greenland the "ground zero" for climate change threats to the world's ice sheets.

evidence of early human inhabitants of Greenland. Arctic archaeological sites are extremely important globally because so much organic material, such as wood, bone, animal skins and hair, is preserved in frozen ground as the process of decay has been halted. Warming conditions in the Arctic are now rapidly leading to the loss of many archaeological resources that are vital for understanding the everyday and spiritual lives of the first peoples to live in these often inhospitable lands. Thawing permafrost, loss of sea ice leading to coastal erosion, and increasing tundra fires are putting archaeological sites and historic monuments at risk throughout the Arctic.

The Disko Bay region is rich in archaeological resources (Weidick and Bennike 2007), including one of the best preserved sites for palaeo-Eskimo cultures in Greenland at Qajaa, where Dorset, Saqqaq and Thule people lived in settlements at various times over at least the last 3 500 years. Archaeologists have been excavating kitchen middens, or waste heaps, from these three cultures, where organic remains have been remarkably well preserved for millennia. Warming conditions are now thawing the permafrost and decomposition of organic matter in the middens is occurring.

Feedback mechanisms at work

A team of Danish scientists working at Qajaa have recently reported that wooden artefacts – preserved for more than 4 000 years in the permafrost but exposed to summer thaw over the last 30 years – are markedly degraded (Matthiesen *et al.* 2013). Laboratory experiments show that the decay of the archaeological deposits is temperature-dependent, with rates increasing by

The warming of Greenland's soils is releasing stored carbon into the atmosphere and contributing to climate feedback mechanisms that are threatening sites throughout the Arctic.

10–20 per cent for each 1° C of warming (Hollesen *et al.* 2015, 2012). In addition, the metabolism of bacteria actively decomposing the organic deposits in the thawing permafrost layer generates heat, which in turn accelerates the thawing of the frozen ground (Hollesen *et al.* 2015). This positive feedback cycle can speed the deterioration of vital evidence of the early inhabitants of Greenland as well as increasing the release to the atmosphere of carbon stored in the frozen soil. Model results suggest a critical shift from a first phase of relatively slow permafrost thaw, driven by climate change and low heat production, to a second phase of accelerated permafrost thaw when water is drained and increasing oxygen availability markedly triggers a higher internal heat production. If this tipping point is reached, the heat production can accelerate decomposition and the archaeological clues that can help us understand our ancestors' lives in Greenland could be lost forever within 80–100 years.

The warming of the Earth's atmosphere and oceans, the faster rate at which the Arctic is warming in comparison to the rest of the globe, and the impacts of this warming on the melt rate of Jakobshavn Glacier, are as stark a warning of the seriousness of climate change as it is possible to get. Greenland is ground zero for climate change threats to the world's ice sheets. Research shows that rates of global sea-level rise have approached 1 metre per century in association with previous warming periods in the geological past, and these rates could reoccur in the future. Climate models suggest that the Greenland ice sheet could melt during the next 1 000 years and that a threshold triggering many metres of sea-level rise from ice sheet melting could be passed this century (Overpeck *et al.* 2006).

Heart of Neolithic Orkney, UK; Stonehenge, Avebury and Associated Sites, UK

HEART OF NEOLITHIC ORKNEY
Date of inscription: 1999
Criteria: (i), (ii), (iii), (iv)
Significance: technologically ingenious and architecturally unique Neolithic monuments; extraordinary evidence of cultural and ceremonial traditions and the interchange of human ideas

STONEHENGE, AVEBURY AND ASSOCIATED SITES
Date of inscription: 1986
Criteria: (i), (ii), (iii)
Significance: most architecturally sophisticated (Stonehenge) and largest (Avebury) prehistoric stone circles in the world; unparalleled ceremonial landscapes

The Neolithic monuments of the Orkney Islands off the north coast of Scotland and at Stonehenge and Avebury in southern England are among the most remarkable Stone Age remains anywhere in the world.

Stonehenge is the most architecturally sophisticated stone circle on the planet, and Avebury – at just more than 300 metres in diameter – is the largest (UNESCOb). Nearby Silbury Hill, also part of the World Heritage site, is the largest man-made mound in Europe, comparable in size to the Egyptian pyramids (Stonehenge and Avebury World Heritage Site). More than 1 000 kilometres north on Mainland, the biggest of the Orkney Islands, lies a group of archaeological sites that make up the Heart of Neolithic Orkney World Heritage property, pre-dating Stonehenge by at least 200 years. The sites comprise 5 000-year-old Skara Brae, the best preserved Neolithic settlement in northern Europe; the Ring of Brodgar; the Stones of Stenness; and the large chambered tomb of Maes Howe, famous for the alignment of its entrance passageway with the setting mid-winter sun (UNESCOc). The tomb was broken into by Vikings in the 12th century and contains the largest collection of Viking graffiti and runes ever found in the UK (Roberts 2002).

Together, the monuments of the Heart of Neolithic Orkney World Heritage site offer extraordinary testament to the living conditions, material culture, and burial and ritual practices of the Stone Age farmers who arrived in Britain about 6 000 years ago (UNESCOc). Orkney was clearly a centre of innovation and experimentation – pottery decorated with grooves that later became common in Neolithic Britain started here, as did decoration of interior walls with red, black and white stains (Ravilious 2015). The architectural and ceremonial creativity that is evident in Orkney's stunning monuments gave rise to later monuments at Carnac in France as well as Stonehenge and Avebury, as ideas and material goods spread out from this maritime centre of Stone Age innovation.

Climate change will alter the environmental conditions at these monuments and their associated landscapes and the ability to manage consequent change in environmental processes will determine how much a changing climate threatens these places. In Orkney, sea-level rise, the increasing frequency of storms and accelerated coastal erosion present major threats (Dawson 2013; Historic Scotland 2013), whilst Stonehenge and Avebury may be sensitive to increasingly extreme weather, including storms and flooding (UNESCO 2014).

The development of sustainable tourism is an important economic objective in Orkney. Despite its remote location, Skara Brae alone receives about 70 000 visitors annually and is one of the top ten visitor attractions for Historic Scotland – the other nine mostly being famous castles on Scotland's mainland. Visitor numbers are growing, in part due to the increase in cruise ships visiting the islands – now numbering about 80 a year. The tourism industry in Orkney generated US$ 31 million in revenue in 2012–2013 and is increasingly important to the islands, particularly as fishing has dramatically declined in recent decades. More than 50 per cent of visitors to Orkney say they go because of the history and archaeology (Gibson 2014).

Nationwide change

For the UK as a whole, recent warming has been consistent with recorded trends over the last 45 years both globally and in northwestern Europe. For most of the UK, summers are becoming hotter and drier and winters significantly warmer and wetter. A greater proportion of precipitation is coming in extreme events, and sea levels are rising at varying rates around the UK's coast. Temperatures in the southeast of England are projected to rise by 1–8°C by the 2080s, slightly

Five-thousand-year-old Skara Brae is on the front-line of sea-level rise and at risk from coastal erosion.

above the global average projection of 1–6°C (UNESCO 2014; UKDEFRA 2012), while the volume of winter rainfall could increase by as much as 70 per cent by the 2080s (UNESCO 2014). In Scotland there has already been a significant increase in heavy rainfall events in all regions since 1961 and, especially in the 1990s, there was a higher frequency of storms (Werrity *et al.* 2012). Increases in wind speeds and extremes are predicted for Scotland and storm surges may also become more frequent (Kovats *et al.* 2014).

Sea-level rise, increased storm frequency and intensity, and coastal erosion are major threats to coastal heritage throughout the UK. Some 17 per cent of the UK's coast is eroding and storm damage is expected to increase (Masselink and Russell 2013). Scotland has northern Europe's longest coastline aside from Norway, and conservative estimates suggest that 12 per cent of it is eroding. Of 11 500 archaeological and historic sites surveyed between 1996 and 2011, nearly a third were assessed as needing some sort of action or protection (Dawson 2013).

Thought of as remote today, Orkney was for centuries an important maritime centre for trade and cultural exchange going back to around 3000 BC (Gibson 2014). Because of the importance of the sea in Neolithic life in Orkney, many archaeological sites are on the coast, and at least half are under threat from coastal erosion (Gibson 2014). Skara Brae is the highest-profile site at risk of eventual loss from coastal erosion – it was discovered when a storm blew away sand and ripped turf from the site in 1850, uncovering parts of the ruins of what turned out to be the best-preserved Stone Age dwelling complex in Western Europe, complete with stone houses, stone furniture including seats and shelves, and archaeologically rich middens or waste heaps (Gibson 2014). A sea wall was first constructed to protect Skara Brae from erosion in 1925 and periodic improvements have been made ever since, but the coast is eroding at either end of the wall.

Meanwhile, in southern England, the world's most famous Stone Age monument is being managed to minimize the impacts of growing tourism and the site's potential sensitivities to changes in the climate. The huge megaliths of bluestone and Wiltshire Sarsen, some weighing more than 40 tonnes, attract more than 1 million visitors a year. A recent climate vulnerability assessment carried out by UNESCO and Historic England identified a wide range of ways in which climate change could affect the site. Warmer winters are likely to bring higher populations of burrowing mammals including badgers, moles and rabbits, which may destabilize stonework and disturb buried archaeological deposits. Hotter drier summers could increase the number of visitors, and could change the plant species in the grassland that currently stabilizes the site's chalk downlands, exacerbating soil erosion problems.

Of most concern for Stonehenge are increasing rainfall amounts, more extreme rainfall events and worsening floods. Flash floods can result in damage through gullying and wetter conditions are also expected to increase the impact of visitors walking on the site. Thirty kilometres away, extreme rainfall recently led to the River Kennet overflowing its banks and causing floods at both Avebury and Silbury Hill (UNESCO 2014).

Archives at risk

In Scotland, although Skara Brae is safe for the moment, many other archaeological sites are at risk of destruction by the sea. The threatened sites contain archives of data that can help inform society about human adaptation to previous changes in climate. If no action is taken, however, these archives will be lost. Scotland's Coastal Heritage at Risk Project (SCHARP) is adopting an innovative citizen-science approach to such sites, working with local communities who report new discoveries, update databases and get involved in practical projects, including excavations.

Wadden Sea, Netherlands, Germany and Denmark

Date of inscription: 2009
Criteria: (viii), (ix), (x)
Significance: largest unbroken system of intertidal sand and mudflats in the world; globally important site for migratory birds

The Wadden Sea is the largest unbroken system of intertidal sandflats and mudflats in the world. The World Heritage site stretches from the Dutch Wadden Sea Conservation Area through the German Lower Saxony, Hamburg and Schleswig-Holstein Wadden Sea National Parks, which were all inscribed on the World Heritage List in 2009, to the Danish Wadden Sea Maritime Conservation Area which was added to the site in 2014 (UNESCOd).

With 1 143 403 hectares, this tri-national site encompasses a multitude of transitional habitats between land, freshwater and marine environments, including tidal channels, sandy shoals, seagrass meadows, mussel beds, sandbars, mudflats, salt marshes, estuaries, beaches and dunes. Such a diversity of landscapes makes the Wadden Sea a unique habitat for numerous animal and plant species; it is also considered one of the most important global migration areas, with an average of 10–12 million birds passing through the site every year (UNESCOd).

It is not surprising that, with its diversity of wildlife and beautiful landscapes, the Wadden Sea has for many decades been a major European tourist destination. About 10 million tourists visit this World Heritage site every year, with about 50 million overnight stays and 30–40 million day trips, bringing an estimated EUR 3–5 billion (*c.* US$ 3.4–5.7 billion) to the Wadden Sea region every year (CWSS 2014a). It has been estimated that one out of five jobs in the Schleswig-Holstein part of the Wadden Sea area is related to tourism, which means that approximately one third of the population of that area depends on tourism; the situation in Denmark and the Netherlands is probably comparable (Stevens and Associates 2006).

Tourism services are well developed in many parts of the Wadden Sea and offer a wide range

of options. In addition to typical beach activities such as sunbathing, walking along the sands and swimming at high tide, many tourists venture onto the mudflats themselves. People believe that walking on the mudflats (Wattwandern) is a very healthy activity due to the changing surfaces underfoot (Alberts 2015).

As successful as the protection of the area has been over the years, a number of problems remain for which solutions compatible with the sea's protection goals need to be found. In the long term the most important of these may well be climate change and its expected impacts, a major concern in the Wadden Sea region with numerous studies and scientific papers dedicated to this subject. A number of key issues and potential climate change impacts have been identified, including direct effects of sea-level rise, disturbance of natural processes and loss of habitat for many species.

The morphodynamic development of the Wadden Sea is influenced by changing environmental conditions such as sea-level rise, as well as by human interference (Wang *et al.* 2012). Sea-level rise, with increased frequency of storm surges and higher inputs of energy, could lead to the dwindling of intertidal areas and increase the risk of coastal lands being flooded (Stevens and Associates 2006). Erosion of beaches, mudflats and salt marshes, and other coastal damage may increase due to accelerated sea-level rise (Fitzgerald *et al.* 2008).

Sea-level rise may also significantly change the morphology and ecology of the Wadden Sea system, threatening habitats and several species including birds and seals (Van Goor *et al.* 2003). Due to its sediment-importing capacity, the system has been able to cope with rising waters for many centuries, but the accelerated rate of rise expected as a result of climate change

The Wadden Sea attracts about 10 million visitors a year.

may cause a loss of intertidal flats and salt marshes, leading to a decline in foraging and nesting possibilities for migratory and breeding birds (MELUR-SH 2015; Bairlein and Exo 2007; Brinkman *et al.* 2001). As a result of temperature rise, the plankton at the base of the food web may change, which could lead to changes higher up in the food web, including lower reproduction levels of fish populations and decreasing bird populations (NEAA 2014). In an ecosystem as complex as the Wadden Sea, the effects of climate change may also result in a cascade of yet unknown but wide-ranging changes.

Shifts in ecosystem functioning will inevitably have consequences for sustainable use (Philippart and Epping 2009). This could include negative impacts on the provision of environmental services such as breeding, nursery and feeding grounds for commercially valuable fin and shell-fish (Stevens and Associates 2006). Freshwater availability on some of the Wadden Sea's islands may also become an issue due to projected lower summer and higher winter precipitation (CWSS 2014b).

Due to the complexity of geophysical and biological interactions in the Wadden Sea system, projections on the direction and magnitude of all of these factors still constitute a major scientific challenge. However, action is required now if future difficulties are to be successfully overcome.

The Wadden Sea is a destination that attracts tourists who want to go on holiday near where they live rather than travelling hundreds of miles to distant beaches. As a result, it can make a significant contribution to global climate solutions by avoiding the long-distance flights that are a major contributor to greenhouse gas emissions. In addition, however, Wadden Sea managers are implementing several innovative projects that make the Wadden Sea a ground-breaking destination in terms of climate friendliness. Initiatives include five completely car-free North Sea islands, an extremely low-cost (EUR 1 per ticket) tourist bus service in the Ostfreisland region that serves 4 900 bus stops on about 250 routes, and a system of certification for climate-friendly accommodation (Günther *et al.* 2013).

Recognizing that "climate change and enhanced sea-level rise may seriously impact structure, functions and characteristic biodiversity of the Wadden Sea ecosystem, as well as the safety of the inhabitants of the region", in 2014 the Trilateral Wadden Sea Governmental Meeting adopted the Trilateral Climate Change Adaptation Strategy (CWSS 2014b), the overall goal of which is "to safeguard and promote the qualities and the integrity of the area as a natural and sustainable ecosystem whilst ensuring the safety of the inhabitants and visitors".

In 2015, initial thoughts about how to prepare for accelerating sea-level rise and identify the right steps for action were developed in more detail for the Schleswig-Holstein part of the Wadden Sea, covering about one third of its entirety. The regional government adopted the Strategy for the Wadden Sea 2100 (MELUR-SH 2015), which had been developed by a stakeholder group consisting of the coastal defence and national park administrations, and representatives from the island communities and two environmental non-governmental organizations including the global conservation organization WWF. This is expected to heavily influence the way in which the coastal defence administration will develop and effect measures in the future. As a contribution towards implementation of the strategy, WWF published a report with 13 case studies of international climate adaption efforts along "soft coasts" such as the Wadden Sea (Fröhlich and Rösner 2015).

Although the effects of climate change may potentially have direct negative impacts on nature-based tourism in the Wadden Sea (Schasfoort and van Duinen 2014), some solutions can be developed to help minimize the impacts of the tourism sector itself and make it part of the solution.

At the 11th Governmental Wadden Sea Conference on the island of Sylt in 2010, the ministers declared their intention "… to work towards developing the Wadden Sea Region into a carbon dioxide neutral area by 2030 or before …", and in 2014 the Trilateral Wadden Sea Governmental Meeting adopted the strategy for *Sustainable Tourism in the Wadden Sea World Heritage Destination* (CWSS 2014c). The document recognizes that "environmentally friendly transport and accommodation are an important way to manage visitor flows. They will also contribute to the survival of the Wadden Sea World Heritage property and raise its profile as a carbon dioxide neutral tourist destination".

A feasibility study on climate-friendly tourism in the Wadden Sea region, conducted on behalf of WWF-Germany (Günther *et al.* 2013), highlights various possibilities to minimize carbon dioxide emissions associated with tourism, including from local mobility, catering and accommodation. The study emphasizes that a lot more could be done by the tourism industry to contribute to the achievement of the climate goal jointly set by Denmark, Germany and the Netherlands, according to which the Wadden Sea region should become climate-neutral by 2030.

The Wadden Sea is home to a rich diversity of plant and animal species, including harbour and grey seals.

Venice and its Lagoon, Italy

Date of inscription: 1987
Criteria: (i), (ii), (iii), (iv), (v), (vi)
Significance: incomparable artistic and architectural achievement; architectural and monumental evolution; history of maritime trade and exploration

Venice is one of the World Heritage sites most at threat from sea-level rise, with major implications for its burgeoning tourism industry. The city's extraordinary assemblage of Byzantine, gothic, renaissance and baroque architecture is under immediate threat from rising sea levels.

Founded in the 5th century, Venice was built on the islands and marshes of the Venetian Lagoon as a trading post and refuge from attack. The villages and settlements expanded, and between the 9th and 15th centuries Venice was an immensely powerful and rich trading state. Today, the city stands on 118 islands with connected canals and 338 bridges (World Monuments Fund). Venice is now one of the world's most popular and iconic tourist destinations, hosting nearly 10 million overnight visits in 2013 (Città di Venizia 2014) and at least twice as many day visitors (A.S. Cocks, pers. comm.).

But tourism itself is becoming a major concern as the dramatic increase in visitor numbers and, in particular, the number of single day trips, has radically changed the visitor dynamic in Venice in recent years. Cruise ship disembarkations rose nine-fold between 1990 and 2011, from 200 000 to 1.8 million (Cocks 2013).

The Venice Port Authority has indicated that the income and employment generated by cruise tourism is indispensable to the city – cruise ship passengers alone are said to spend up to EUR 150 million (*c.* US$ 170 million) in Venice each year (Comitato Cruise Venice) – and has promoted deep dredging in the lagoon to enable ships to enter the port without sailing through the town. Alternative proposals have also been made, including allowing the ships to dock on the mainland shore inside the lagoon, or building a floating dock in the sea outside one of the lagoon's entrances.

Today, in the face of such rapid tourism growth alongside rising sea levels driven by climate change and worsened by local land subsidence, Venice is struggling to maintain both the fabric of its buildings

and the character of the city. As tourist numbers have continued to grow, the resident population has dropped dramatically – from 120 000 to 55 000 over the past 30 years – with people leaving as a result of high consumer prices, congestion, a lack of affordable places to live (Ross 2015).

Catastrophic storm damage

The worst flood in recent memory was in November 1966, when a massive storm system hit Italy, causing catastrophic damage to art and cultural heritage in Florence in the west and Venice in the east (Malguzzi *et al.* 2006). Venice and its inhabitants have for centuries struggled with the water and the maintenance of the lagoon, and have had to find ways to live with the high tides and storms. But the 1966 event provoked major discussion about how to protect Venice from future catastrophic floods. After decades of debate and planning, a series of 79 flood gates distributed across the three entrances that connect the Venetian Lagoon to the Adriatic Sea – the MOSE project – is due to be completed in 2017. These gates will rise whenever a tidal flood of 110 centimetres or more is predicted (Windsor 2015; Tosi *et al.* 2013), holding back the waters of the Adriatic until conditions improve. The total cost of these defences will be above EUR 5.4 billion (US$ 6.1 billion), and maybe more.

Venice's waters have risen by some 30 centimetres since the end of the 19th century.

Flooding at especially high tides or as a result of storm surges has always been an issue for Venice. But now, with sea levels rising, the problem is becoming much more severe. For decades the problem of sea-level rise has been exacerbated by land subsidence caused by water extraction – a practice that was ended in the 1970s to prevent Venice from sinking further. Venice has seen water levels rise by nearly 30 centimetres in relation to the measuring point established in 1897 beside the Punta della Dogana, an art museum in Venice's old customs building, the Dogana da Mar. Of this, about 12 centimetres is due to land subsidence and the rest to climate-driven sea-level rise (UNESCO 2011; Carbognin *et al.* 2010).

The ever more frequent flooding events experienced by the city in the last 60 years will be controllable when the mobile barriers between the lagoon and the sea come into operation, at least until sea levels eventually overwhelm them, too (UNESCO 2011). The water level in the lagoon, however, will continue to rise, eating away at the substance of the buildings as damp spreads up the brickwork. The barriers will be ineffective against this phenomenon, except by being closed for longer and longer periods, with significant water pollution implications for the lagoon (UNESCO 2011).

Early design features beset by high tides

Hundreds of buildings and monuments in Venice have already been damaged by rising seas. The city's buildings were originally constructed by driving wooden posts deep into the mud of the lagoon, with dense, water-resistant Istrian stone foundations laid on these pilings and the fabric of the house built on top using brick, plaster and marble. A projecting stone moulding that separates the stone from the brick prevented waves from splashing upwards and wetting and

The ever more frequent flooding events experienced by Venice in the last 60 years will be controllable when mobile barriers between the lagoon and the sea come into operation in 2017.

damaging the brickwork (Camuffo *et al.* 2014). But the water level is now often above the stone bases at high tide and the damp then rises by capillary action. Damage is caused by salts in the bricks or stone dissolving and then recrystallizing – San Polo Church, for example, has been severely affected (Camuffo 2001). The situation has been made worse by the dredging of deep-water channels for shipping, allowing more sea water to enter the lagoon and increasing the salinity of the water (Camuffo 2001; Penning-Rowsell 2000).

Where the waters have risen above the stone foundations, damp is rising to higher levels where it decays the iron tie-rods that stabilize buildings and hold their walls together, deteriorating the marble and, in St. Mark's Basilica, damaging the small tiles (*tesserae*) of the 1 000-year-old mosaics placed 6 metres above the floor (Cocks 2013). Statues and monuments, too, are being damaged; for example, the marble statues of the cenotaph built by the 18th century Venetian sculptor Antonio Canova in the Santa Maria Glorioso dei Frari Basilica, are rapidly deteriorating as a result of water entering the building and being drawn up into the marble by capillary action, eventually emerging on the surface of the statues, causing areas of flaking and blistering. The statues are now wet more often than they are dry, and restoration will require waterproofing the room, dismantling the monument, removing the salts from the stone, sealing the bases of the statues and then reassembling the whole (Camuffo *et al.* 2014).

Venice is now under assault from rapidly growing tourist numbers as well as worsening climate-driven water damage to the very buildings, and architectural and monumental heritage that draw visitors in the first place. Ironically, tourism is responsible for thousands of Venetian jobs and tens of millions of dollars in revenue to the city and its businesses, but the effects of climate must be addressed if the historic centre is to survive at all, and tourism must be better controlled if Venice is to remain a thriving and diverse community.

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World Heritage and Tourism in a Changing Climate

World Heritage and Tourism in a Changing Climate provides insights into the vulnerability of World Heritage sites to climate change and its potential implications for the global tourism industry. It examines the close relationship between World Heritage and tourism, and how climate change is likely to pose new challenges and exacerbate existing problems caused by unplanned tourist development and uncontrolled or poorly managed visitor access, as well as other threats and stresses.

World Heritage and Tourism in a Changing Climate, through 12 fully referenced case studies and 18 shorter views of cultural and natural World Heritage sites, shows how climate-driven changes, now and in the future, threaten their outstanding universal value and integrity, as well as the economies and communities that depend on their tourist appeal. The case studies were chosen for their geographic representation, diversity of types of natural and cultural heritage and importance for tourism. Most importantly, they provide examples of a wide range of climate impacts, supported by robust scientific evidence.

Drawing together common themes in the relationship between World Heritage, climate change and tourism, *World Heritage and Tourism in a Changing Climate* presents a series of stakeholder recommendations for action. These aim to help minimize the impacts of climate change on World Heritage properties and promote a more sustainable development of tourism.

The publication has been developed as a contribution to the United Nations 2030 Agenda for Sustainable Development and the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC), funded by the Division of Technology, Industry and Economics of the United Nations Environment Programme (UNEP) and in partnership with the United Nations Educational, Scientific and Cultural Organization (UNESCO), UNEP and the Union of Concerned Scientists (UCS) in collaboration with the International Union for the Conservation of Nature (IUCN).

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