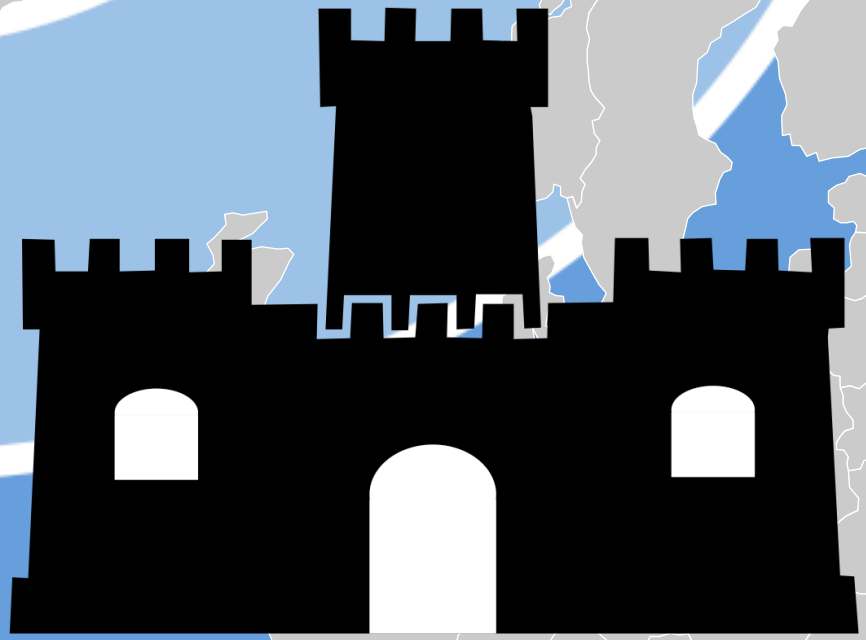
Europe's cultural-historical heritage in a changing climate



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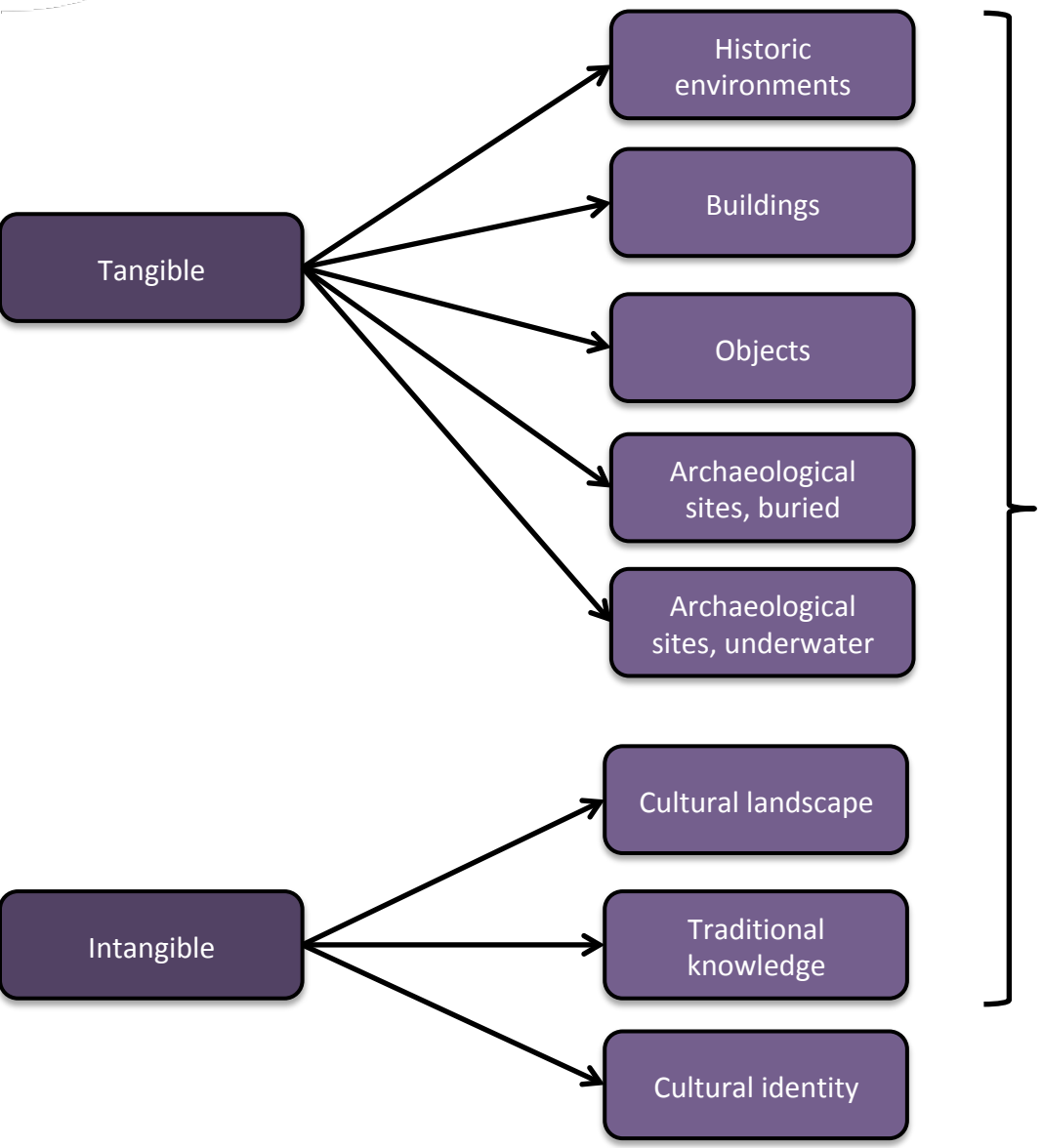
Overview impacts and vulnerabilities



Climate change impacts:

- sea level rise
- flooding
- coastal erosion
- changing air and sea temperatures
- changing humidity
- extreme weather events such as hurricanes, storms, and droughts
- weathering
- changing soil and sediment conditions

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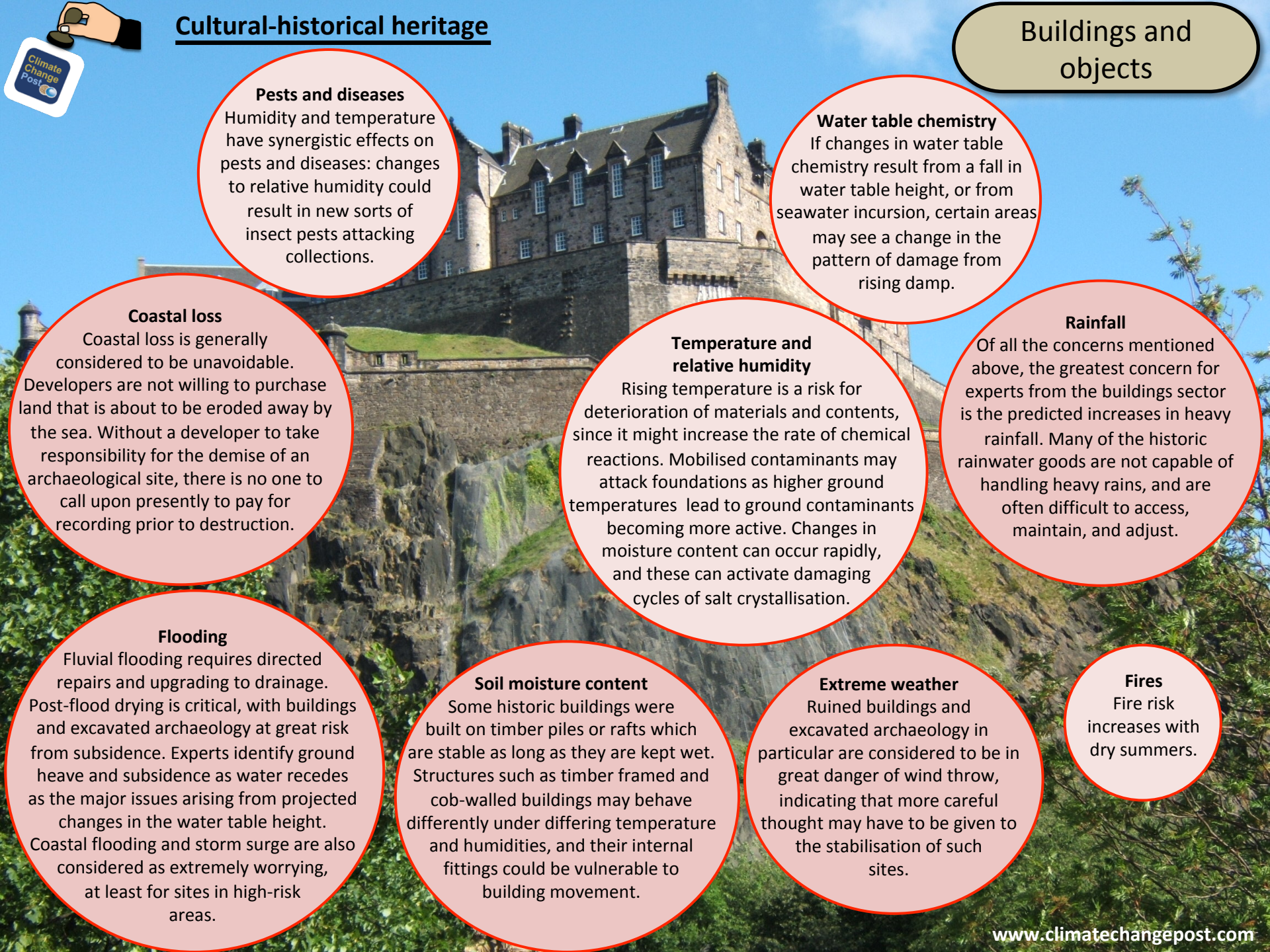
Buildings and objects



Pests and diseases
Humidity and temperature have synergistic effects on pests and diseases: changes to relative humidity could result in new sorts of insect pests attacking collections.

Water table chemistry
If changes in water table chemistry result from a fall in water table height, or from seawater incursion, certain areas may see a change in the pattern of damage from rising damp.

Coastal loss
Coastal loss is generally considered to be unavoidable. Developers are not willing to purchase land that is about to be eroded away by the sea. Without a developer to take responsibility for the demise of an archaeological site, there is no one to call upon presently to pay for recording prior to destruction.

Temperature and relative humidity
Rising temperature is a risk for deterioration of materials and contents, since it might increase the rate of chemical reactions. Mobilised contaminants may attack foundations as higher ground temperatures lead to ground contaminants becoming more active. Changes in moisture content can occur rapidly, and these can activate damaging cycles of salt crystallisation.

Rainfall
Of all the concerns mentioned above, the greatest concern for experts from the buildings sector is the predicted increases in heavy rainfall. Many of the historic rainwater goods are not capable of handling heavy rains, and are often difficult to access, maintain, and adjust.

Flooding
Fluvial flooding requires directed repairs and upgrading to drainage. Post-flood drying is critical, with buildings and excavated archaeology at great risk from subsidence. Experts identify ground heave and subsidence as water recedes as the major issues arising from projected changes in the water table height. Coastal flooding and storm surge are also considered as extremely worrying, at least for sites in high-risk areas.

Soil moisture content
Some historic buildings were built on timber piles or rafts which are stable as long as they are kept wet. Structures such as timber framed and cob-walled buildings may behave differently under differing temperature and humidities, and their internal fittings could be vulnerable to building movement.

Extreme weather
Ruined buildings and excavated archaeology in particular are considered to be in great danger of wind throw, indicating that more careful thought may have to be given to the stabilisation of such sites.

Fires
Fire risk increases with dry summers.

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Buried archaeology

Plant physiology and distribution

Changes in vegetation cover will greatly affect the survival of buried sediments and artefacts and ecofacts. Deep root penetration is very damaging to structures and sediment boundaries. There is also the problem of dewatering by transpiration, and loss of vegetation cover through drought could also exacerbate erosion.

Soil chemistry and moisture content

Waterlogged, anaerobic conditions can preserve a wide range of archaeological artefacts, including those made of leather, wood and other organic materials. These artefacts are rare and important. Crucial environmental evidence is also preserved, including ancient pollen, seeds, wood, insects, bone and molluscs. The survival of these remains is linked to the chemical composition of the deposits in which they are contained. Lowering or fluctuating water levels, or pH changes, may have a significant impact on preservation. For wetlands sites, archaeologists are expecting a very serious loss of these artefacts and remains.

Drying of the soil may disturb the archaeological record because the stratigraphic integrity will be lost if they crack and heave due to changes in sediment moisture. Strong changes between water levels for summers and winters will have a tremendous effect on those sites which are situated in the area of dry-wet cycles.

Changes in (agriculture) land use

Farmland contains the vast majority of archaeological sites and agriculture is one of the greatest causes of their destruction. A shift towards a more 'Mediterranean' climate would also shift cultivation limits and patterns, with some new areas coming under plough. Deep ploughing is particularly destructive of buried archaeological remains. Climate predictions suggest that new areas would be amenable to colonisation by woodland, or to commercial or private plantation. Tree growth can be very damaging to both above-ground and buried sites and features, through root growth and root-pull resulting from tree-blow.

Pests and diseases

Additional temperature-related effects relate to biological decay, for instance due to termites and the oakbeam-eating deathwatch beetle.

Flooding

Many sites will be endangered by sea level rise and storm surge. Sites vulnerable to erosion will also be at risk from increased storminess and tidal range. Increased flood frequency and inundation of river corridors resulting from high waters in estuarine areas, and from increased precipitation leading to greater river volume, may also have a significant impact.

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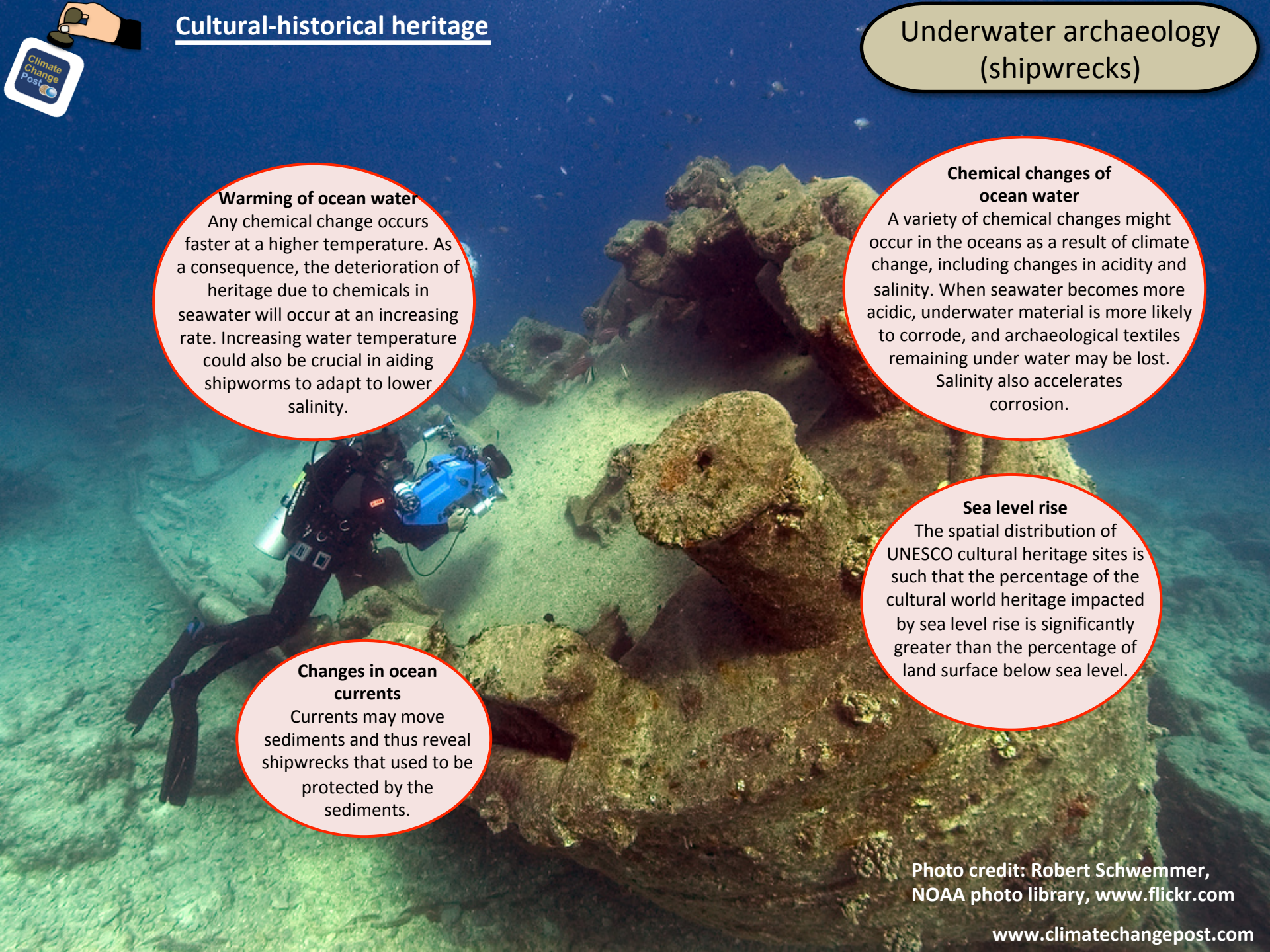
Underwater archaeology (shipwrecks)



Warming of ocean water
Any chemical change occurs faster at a higher temperature. As a consequence, the deterioration of heritage due to chemicals in seawater will occur at an increasing rate. Increasing water temperature could also be crucial in aiding shipworms to adapt to lower salinity.

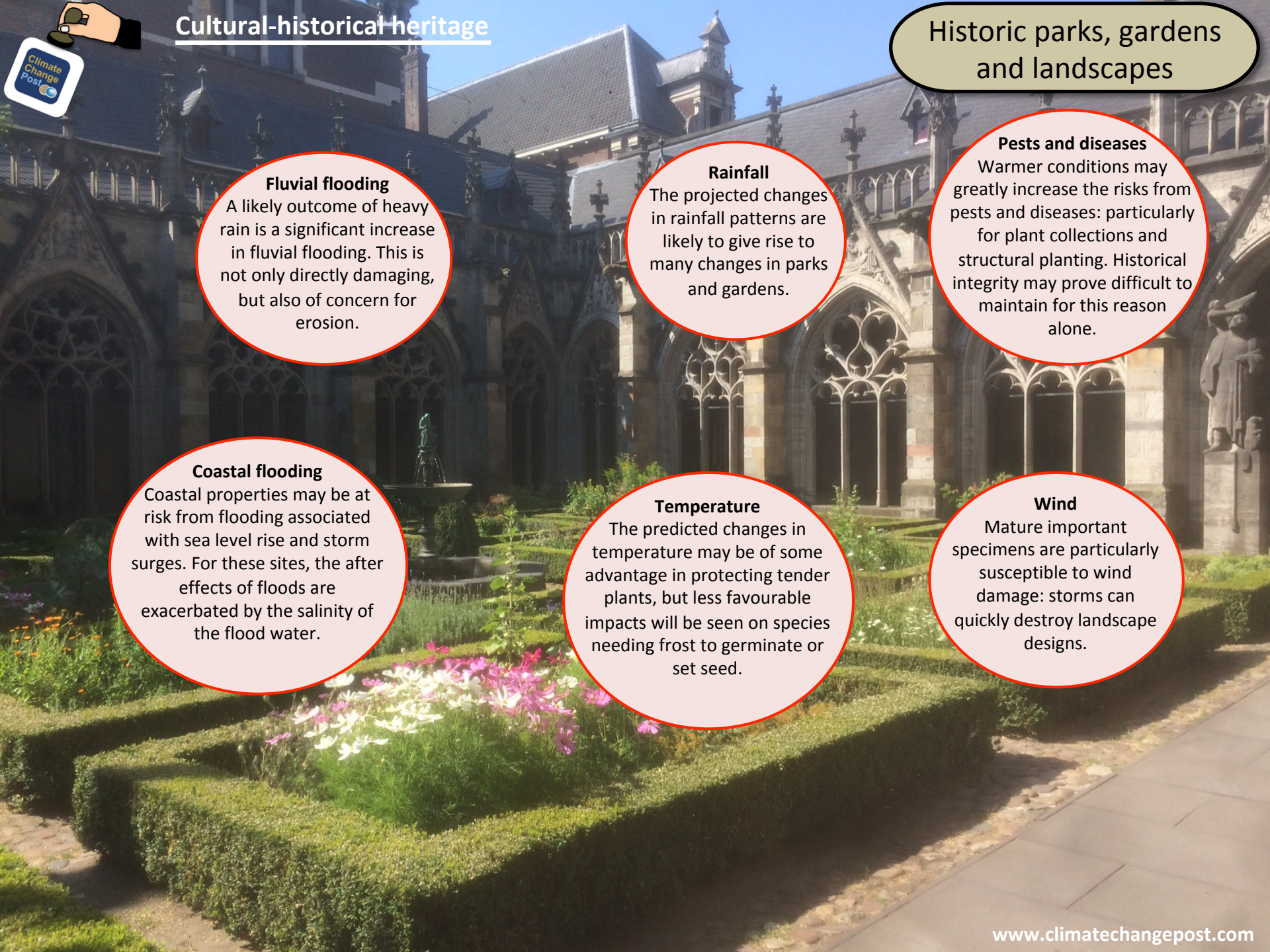
Chemical changes of ocean water
A variety of chemical changes might occur in the oceans as a result of climate change, including changes in acidity and salinity. When seawater becomes more acidic, underwater material is more likely to corrode, and archaeological textiles remaining under water may be lost. Salinity also accelerates corrosion.

Sea level rise
The spatial distribution of UNESCO cultural heritage sites is such that the percentage of the cultural world heritage impacted by sea level rise is significantly greater than the percentage of land surface below sea level.

Changes in ocean currents
Currents may move sediments and thus reveal shipwrecks that used to be protected by the sediments.

Photo credit: Robert Schwemmer, NOAA photo library, www.flickr.com

Historic parks, gardens and landscapes



Fluvial flooding
A likely outcome of heavy rain is a significant increase in fluvial flooding. This is not only directly damaging, but also of concern for erosion.

Rainfall
The projected changes in rainfall patterns are likely to give rise to many changes in parks and gardens.

Pests and diseases
Warmer conditions may greatly increase the risks from pests and diseases: particularly for plant collections and structural planting. Historical integrity may prove difficult to maintain for this reason alone.

Coastal flooding
Coastal properties may be at risk from flooding associated with sea level rise and storm surges. For these sites, the after effects of floods are exacerbated by the salinity of the flood water.

Temperature
The predicted changes in temperature may be of some advantage in protecting tender plants, but less favourable impacts will be seen on species needing frost to germinate or set seed.

Wind
Mature important specimens are particularly susceptible to wind damage: storms can quickly destroy landscape designs.

Cultural-historical heritage

Intangible heritage: reindeer husbandry as an examples

Many Indigenous Peoples depend on hunting polar bear, walrus, seals, and caribou, herding reindeer, fishing and gathering, not only for food and to support the local economy, but also as the basis for cultural and social identity. In Scandinavia, especially reindeer husbandry is an important part of the historical-cultural heritage.

Changes in the summer

Positive effects of climate change are an extension of the growing season and plant production increase during the summer grazing (by 20-40%). Towards the end of the century, the growing season may be extended by up to 2-3 months. The lengthening of the time with no snow on the ground and the shorter winters are positive for reindeer. it is during this season that the reindeer build up their reserves of fat and protein to see them through the winter.

Changes in the winter

Reindeer husbandry is important in Lapland, particularly in small communities. Reindeer are also of great cultural value because many of their owners are indigenous Sami people. The impacts of climate change on reindeer populations are expected to be mainly unfavourable. If winters get milder and precipitation increases, snow may be thicker and icy layers may form inside the snow cover. This would make it difficult for reindeer to dig for lichen and their need for supplementary food will increase. The northward advance of the tree line and gradual replacement of lichens with vascular plants may also affect reindeer pastures.

Although reindeer are easy to herd and habituate quickly to new environments, climate change may constrain the original nomadic migration pattern and trigger new and local adaptations, including revision of district range boundaries.

Changes in the summer

The anticipated higher temperatures in the summer can entail problems for the reindeer, as they do not like heat. A changed climate with higher temperatures and increased precipitation can result in much worse insect plagues.

Land use changes

The predicted increase in growing season could also promote the expansion of agriculture in northern Fennoscandia. The ultimate limiting factor for the reindeer industry is access to grazing lands. Historically, agricultural settlements played a major role in displacing reindeer herders from their land. Additional changes in patterns of land use due to global warming include forestry, agricultural and industrial development, and expansion of tourism development. These all impose potential constraints on reindeer.

Photo credit: Heather Sunderland, www.flickr.com

Cultural-historical heritage

Examples from Ireland and the UK

The probable impacts of climate change on three key coastal sites in **Northern Ireland**, the Giants's Causeway, North East Strangford Lough and the Murlough National Nature Reserve, are increased wetness, drier summers, more frequent and longer-lasting storms with associated storm surges, and as a part of the rising sea-level, higher reaching extreme flood levels. The increased erosion will cause the loss of existing foreshores, salt marshes, sand dunes and cause cliff instability and weaken existing sea defences. Among the impacts, sand dune retreat can be considered one of the most worrying.
Northern Ireland possesses some of the most archaeologically rich dune systems in Ireland.
River erosion may potentially destroy or rework the built heritage, such as in-channel structures (bridges, mill dams, fish weirs, revetments, causeways, platforms etc.) and artefacts (logboats, metalwork, fishing equipment etc.).

Neolithic Orkney World Heritage property on the **Orkney Islands** in the north of Scotland pre-dates Stonehenge by at least 200 years. going back to around 3000 BC. 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. The sites comprise 5.000-year-old Skara Brae, the best preserved Neolithic settlement in northern Europe. Skara Brae is the highest-profile site at risk of eventual loss from coastal erosion.

Stonehenge in **England** is the most architecturally sophisticated stone circle on the planet, and Avebury, at just more than 300 metres in diameter, is the largest. Of most concern are increasing rainfall amounts, more extreme rainfall events and worsening floods. Besides, 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.

Ireland's coastal landscape, and its cultural heritage features such as Martello Towers, castles, historic houses and promontory forts, will be affected by increased coastal erosion, more frequent storms and rising sea levels.
Archaeological and industrial heritage sites along Ireland's inland waterways will suffer from changes in river flow and water supply, resulting in both intense rainfall and flooding at times, but also a drying out due to drought and a reduction in the water table during summer months.
Many estuaries of western Ireland contain submerged Mesolithic, Neolithic and Bronze Age land-surfaces that now lie exposed to view at low tide on the estuary mudflats. Climate and sea-level changes are likely to cause widespread erosion of the lower shoreline.

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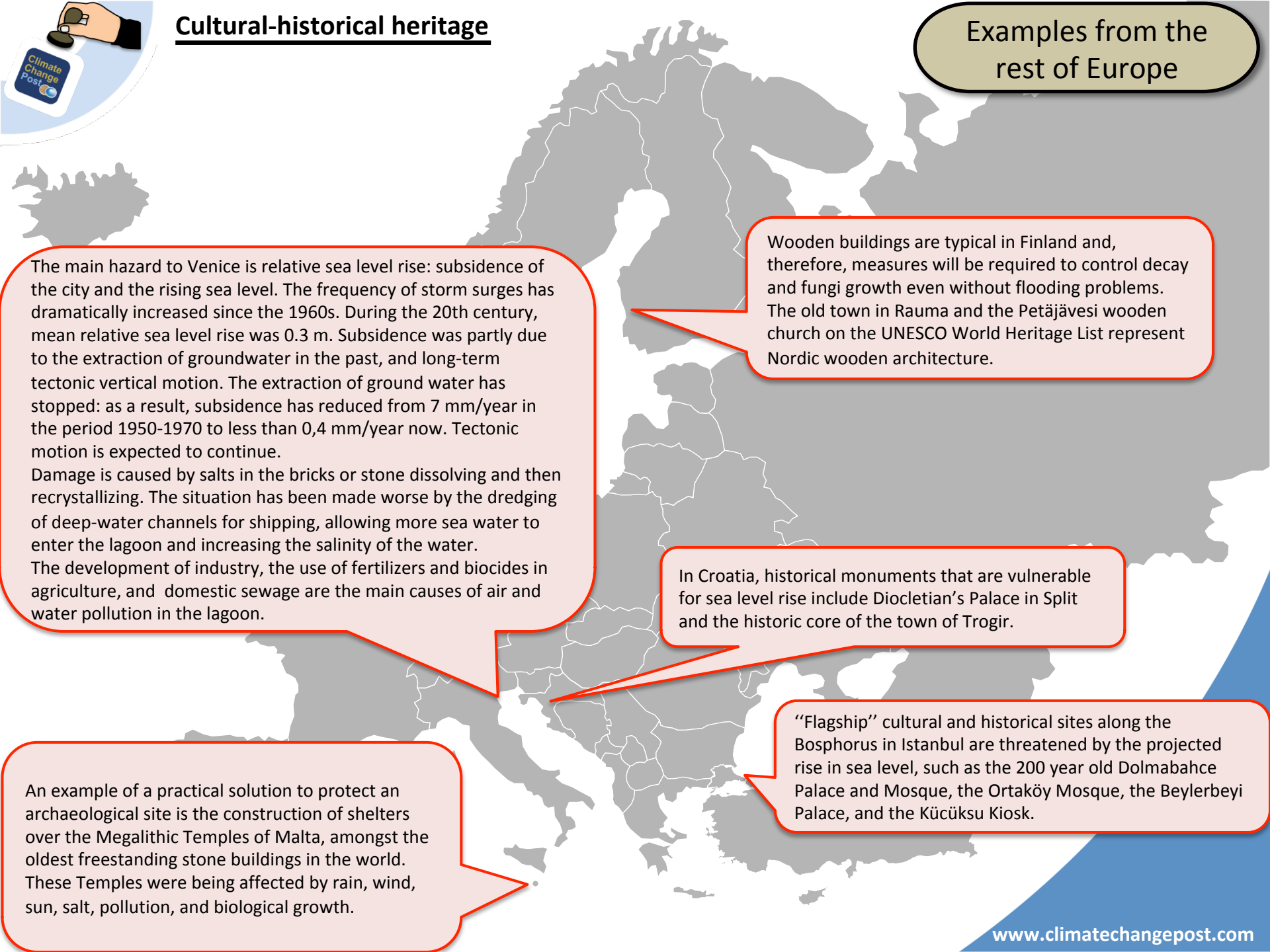
Examples from the rest of Europe



The main hazard to Venice is relative sea level rise: subsidence of the city and the rising sea level. The frequency of storm surges has dramatically increased since the 1960s. During the 20th century, mean relative sea level rise was 0.3 m. Subsidence was partly due to the extraction of groundwater in the past, and long-term tectonic vertical motion. The extraction of ground water has stopped: as a result, subsidence has reduced from 7 mm/year in the period 1950-1970 to less than 0,4 mm/year now. Tectonic motion is expected to continue.
Damage is caused by salts in the bricks or stone dissolving and then recrystallizing. 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.
The development of industry, the use of fertilizers and biocides in agriculture, and domestic sewage are the main causes of air and water pollution in the lagoon.

Wooden buildings are typical in Finland and, therefore, measures will be required to control decay and fungi growth even without flooding problems. The old town in Rauma and the Petäjävesi wooden church on the UNESCO World Heritage List represent Nordic wooden architecture.

In Croatia, historical monuments that are vulnerable for sea level rise include Diocletian's Palace in Split and the historic core of the town of Trogir.

''Flagship'' cultural and historical sites along the Bosphorus in Istanbul are threatened by the projected rise in sea level, such as the 200 year old Dolmabahce Palace and Mosque, the Ortaköy Mosque, the Beylerbeyi Palace, and the Kücüksu Kiosk.

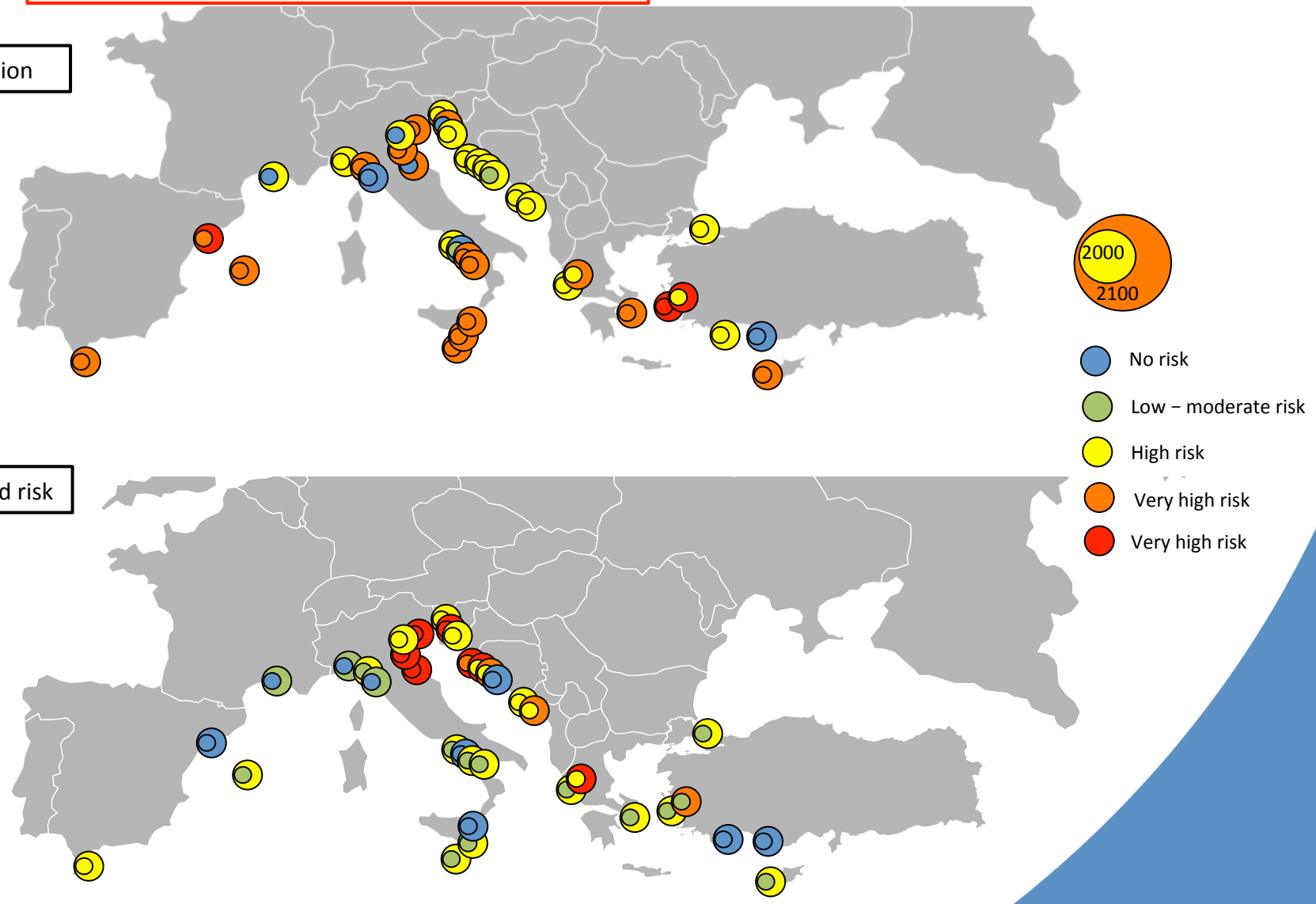
An example of a practical solution to protect an archaeological site is the construction of shelters over the Megalithic Temples of Malta, amongst the oldest freestanding stone buildings in the world. These Temples were being affected by rain, wind, sun, salt, pollution, and biological growth.

Cultural-historical heritage

Of the 49 UNESCO World Heritage sites in low-lying coastal areas of the Mediterranean, already today 37 are at risk from a 100-year flood and 42 from coastal erosion.
(Source: Reimann et al., 2018)

UNESCO World Heritage in the Mediterranean

Coastal erosion



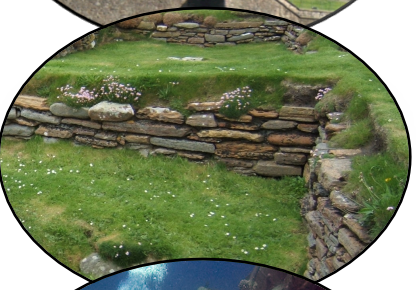
Coastal flood risk

Cultural-historical heritage

Adaptation strategies

Buildings and objects:

- Responding to climate change may lead to an increase in maintenance costs. For example, rainwater disposal systems on buildings may need to be redesigned and updated. Increased frequency of building inspections and attention to repair of defects in roof coverings will be increasingly essential.



Buried archaeology:

- Conservation plans need to focus on deterioration mechanisms, and monitoring and maintenance.
- Practical actions on archaeological sites can include backfilling of excavated sites and covering heritage with shelters or coatings.

Underwater archaeology:

- Underwater cultural heritage (shipwrecks, for instance) is well protected under the water. Cold temperatures and currents in a deep-water environment have a strong preservative effect. Leaving heritage in situ is usually the first option for preserving heritage in both land and underwater sites.

Reindeer husbandry:

- Additional feeding of reindeer may be needed depending on the natural conditions and state of pastures.

Historic parks, gardens and landscapes

- To cope with summer droughts some form of water storage is likely to prove necessary for many sites, but this may be challenging to install invisibly. Drainage redesigned to cope with heavy autumn and winter rain may prove even more difficult to integrate with historic parks and gardens.
- The opportunities for a more diverse choice of plants must be offset against losses of historical integrity, and likely increases in maintenance costs.

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Dilemmas:
We can't save everything!

Which sites to 'let go'	The biggest decision will probably be over which sites to 'let go'. There will never be the money to save everything. Decisions on the value and significance of a site may need to be made upfront before money is spent on short-term or no-real-hope projects.
Acceptance flood losses	Historic sites on the coast will be subject to increased coastal flood risk, whilst inland properties may be at increased risk of fluvial flooding. Such risks will be hard to respond to, as it may not always be appropriate to defend sites, and acceptance of some losses may be necessary.
Preservation by record	If climate change means that deposits begin to deteriorate if not excavated (and thus preserved by recording), the current strategy of preserving in situ may lead to the destruction rather than the preservation of the archaeological heritage. If this is the case, then preservation by record should be favoured wherever possible.
Sacrifice to save the rest	Increases in rainfall intensity are already causing gutters to overflow and drainage pipes to back up. Invisible or non-invasive fixes may not be possible. What aspects of heritage are we prepared to sacrifice in order to save the rest?


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