Climate change impact on the built environment in coastal regions

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1 Introduction

This research is conducted as a part of BEACON (Built Environment leArning for Climate adaptation), a collaborative research project co-funded by the EU Erasmus+ programme of the European Union. This study conducted a detailed review of the climate change impact on the built environment in coastal regions. This study was conducted at two levels: the global level and the next one at the individual country level. The global level review was done through a systematic literature review. The induvial country-level studies were based in the Partner countries United Kingdom, Sweden, Spain, Malta, and Sri Lanka.

This report covers the study for the UK context. The UK context study was also aligned with the global study and framed under four research questions. As the first step of the study climate change evidence in the coastal regions were studied in detail. Then the disaster risk associated with the climate change evidence were investigated in the UK context. Having identified the climate change evidences and the associated disaster risks in the coastal regions the next step was to identify their impacts. The impact study was conducted under four main themes as physical, economic, environmental, and social. Finally, these climate change impacts in the coastal regions were linked to the coastal built environment.

2 Background

The United Kingdom is a maritime nation. According to the statistics, 10-15% of the UK's coastline comprises 10 km long stretches below 5 m elevation, and that 3009 km (16%) is subject to erosion. The study also calculated that 69% of GDP is located within 50 km of the coast and that 78% of the country's population live within this zone(CCA, 2021). Furthermore, coastal zones are socially, economically, and environmentally significant.

Over the last decade, the UK has experienced several severe natural hazards associated with climate change events with significant economic and human impacts on communities, properties, and infrastructure networks. For example, the 2007 summer floods affected 55,000 properties(Dale, 2021). They were estimated to cost £3.2 billion, while the 2013–2014 floods cost approximately £1.3 billion in insurance claims(Smith, 2013). In December 2015, during Storm Desmond, wind gusts of up to 81 mph and record-breaking volumes of rainfall were logged across Northwest England. The storm, and its associated rainfall, is estimated to have flooded 8900 properties with over 100,000 properties left without power, with a cost estimated at £1.3 billion(Hemingway & Gunawan, 2018).

In addition, climate change will cause sea levels to rise continuously throughout the 21st century. Coastal and offshore infrastructure is also vulnerable to changing patterns of storm conditions(Poo et al., 2021). Around £150 billion of assets in the UK are at risk from coastal flooding. Damages to the UK from coastal flooding are estimated to be £500 million per year (Howard & Palmer, 2020). Due to coastal erosion, long-term morphological change is also evident in coastal areas, including extensive salt marsh loss (R. J. Nicholls et al., 2021). While these problems have various causes, climate change due to the anthropogenic greenhouse effect will worsen them (Nicholls, 2000). Sea levels have already risen around most British coasts during the 20th century, inducing rising flood levels. This tendency will develop in the 21st century, and by the 2080s, global sea levels could be between 18 and 99 cm. In addition, increased storminess and more giant waves have contributed to an increased risk of storm damage and flooding in coastal areas(R. J. Nicholls et al., 2021). Many studies relate how climate change negatively affects the ecosystem functioning, agriculture and food security, durability of infrastructure, water resources, human health and causes many other impacts (Hossain et al., 2019). This extended abstract covers one part of the study in which the climate change impacts in coastal regions in the UK are discussed in detail.

Living on England’s coasts comes with a certain level of risk and as per the records in 1953 storm surge killed 307 people in England; and storm Xavier in December 2013 caused over £1.6 billion of damage(CCC, 2018).There are further evidence that the UK climate is changing and year 2020 has been identified as the third warmest, fifth wettest and eight sunniest on record.

Additionally, the coastal belt of the UK becomes nationally important as per the records around 30 million people reside in urban coastal areas and around 40 per cent of manufacturing industry is situated on or near the coast. Furthermore, around 90 per cent of UK trade comes and goes through seaports and the tourism industry evolved based on coastal recreation is a significant contributor to local and regional economies. Accordingly the coastal regions in the UK becomes geologically, socially , economically and culturally important (Zsamboky, Fernández-Bilbao, Smith, & Wilson, 2011).

3 Climate change evidence in coastal regions

The physical characteristics of the UK coastal areas are highly threatened due to the impacts from the climate change scenarios. The long term observations show that air and sea warming, sea ice melting or precipitation changes, sea level rise and ocean acidification are identified to the most severe issues in the UK scenario(MCCIP, 2020).

The primary climate change evidence in coastal regions covers the sea-level rise, weather patterns, temperature variations, and precipitation changes. UK's vulnerability to sea level rise is at the leading level amidst European countries to sea-level rise(CCA, 2021). At present, in the UK, 414,000 people are exposed to sea-level rise (CCA, 2021). Furthermore, sea-level rise impacts changes in tidal range, storm surges, vertical land motion(Gehrels & Long, 2008).In the long run, waves would be affected by seabed evolution. In particular, sea-level rise increases the annual maximum significant wave height over the long narrow sandbanks. Meanwhile, the seabed features and beach profiles will also evolve, resulting in increased wave energy, increasing the potential damages(Chini et al., 2010). Overall the changing weather patterns for the UK suggest that higher temperatures, combined with changing precipitation patterns, will lead to changes in seasonality as well (Gawith, 2005; R. J. Nicholls et al., 2021). The climate change evidence in the UK is furthermore discussed in detail as follows.

3.1 Sea Level rise

Sea levels have already risen around most of the British coast during the 20th Century. This trend is expected to accelerate in the 21st Century and by the 2080s. Sea-level rise is already being experienced in England and Wales (R. J. Nicholls et al., 2021). The cumulated rise in sea levels off the coasts is estimated to exceed 1m (Zsamboky et al., 2011). The figure 1 depicts the sea level rise in the UK over the years. The illustration is based on sea level data from five stations (Aberdeen, North Shields, Sheerness, Newlyn, and Liverpool) in the UK.

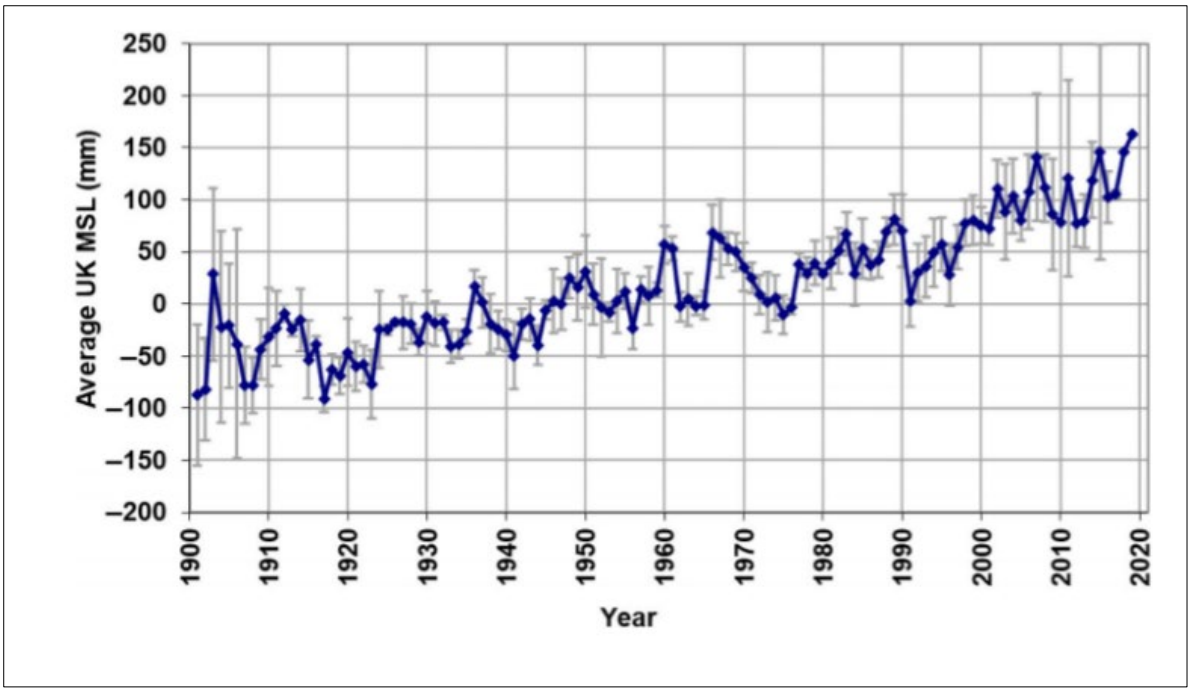

Figure 1: UK sea level index for the period since 1901 computed from sea level data from five stations (Aberdeen, North Shields, Sheerness, Newlyn, and Liverpool) from Woodworth et al. (2009)

Sea level rise is identified to have multiple effects on the coastal line in the Great Britain and induces several coastal hazards as well. Few of them are increased risk of coastal flooding, sediment starvation and erosion and loss/degradation of coastal ecosystems(de la Vega-Leinert & Nicholls, 2008). Changes in sea level are triggered mainly by the thermal expansion of ocean water and the melting of mountain glaciers. Historic trends in vertical land movements will introduce significant regional differences in relative sea level rise around the UK. Accordingly, much of southern Britain sinking and much of northern Britain rising will take place(Gawith, 2005). Furthermore, the magnitude of sea level rise in the UK is influenced by Earth's rotation, oceanic circulation, and local geological changes. It is recorded that parts of Southwest England are sinking at a rate of 0.6 millimetres and on the other side certain parts of Scotland are rising by 1 millimetre per year(Bob & Georgina, 2021).

Sea Level Rise causes changes in tidal range, Changes in storm surges, Vertical land motion (Gehrels & Long, 2008). The impacts of sea level rise mostly occur during the high tides and storms, leading to coastal floods(Bob & Georgina, 2021). The severity and frequency of storm events and coastal flooding are induced by sea level rise (Zsamboky et al., 2011). Additionally, sea level extremes, storm surges will increase height and frequency of the sea waves(Gawith, 2005). Considering long term climate effects, waves would be affected by seabed evolution. In particular, if as found here, sea level rise increases the annual maximum significant wave height over the long narrow sandbanks, these seabed

features could well evolve due to an increase of wave energy. Moreover due to sea level rise, beach profiles will also evolve (Chini et al., 2010). According to the predictions in 2018 , by 2080 up to 1.5 million properties including 1.2 million residential developments are exposed to high level of risk due to coastal flooding(Bob & Georgina, 2021). In the absence of proper adaptation, UK could experience significant impacts on coastal flooding from sea-level rise.

3.2 Changing weather patterns

In terms of the weather change patterns due to the climate change impacts in the coastal regions in the UK still the direct links to wind, wave and storm activity is not properly established. However changes in the ocean and atmospheric *circulation* in the North Atlantic is identified to have impacts on the extreme weather events in the coastal regions in the UK(MCCIP, 2020).

Other changes in climate may have important coastal implications in terms of potential changes in the frequency, intensity, and paths of storms(R. J. Nicholls et al., 2021). In summary, the scenarios suggest that higher temperatures, combined with changing patterns of precipitation, will lead to hotter, possibly drier summers and milder, wetter winters(Gawith, 2005). The figure 2 depicts UK daily area-average rainfall totals for winter 2020(December 2019–February 2020).

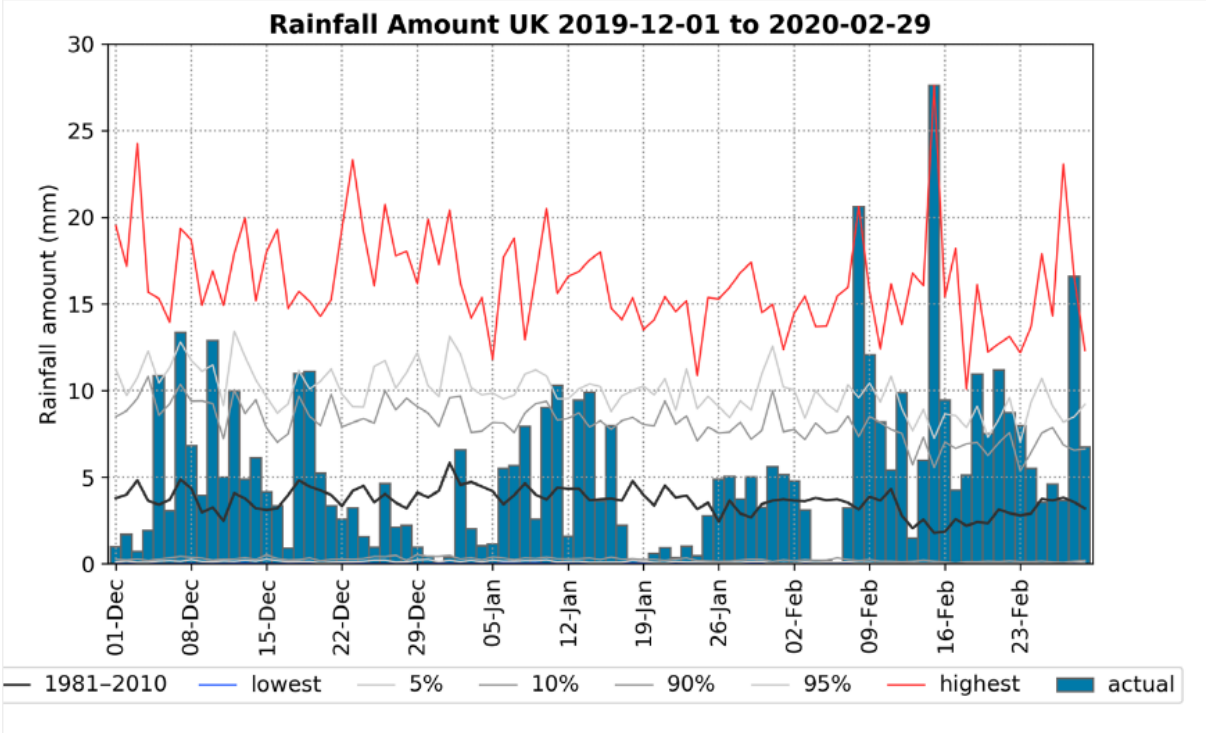

Figure 2: UK daily area-average rainfall totals for winter 2020(December 2019–February 2020)

3.3 Temperature variations

Higher temperatures, with regional and seasonal variation predict by the 2020s, annual warming of between 0.5°C and 1.5°C depending on region and scenario and by the 2050s annual warming of between 0.5°C and 3.0°C depending on region and scenario. Furthermore, greater summer warming in the south east than the north west of the UK; and greater warming in summer and autumn than in winter and spring(Gawith, 2005). Furthermore, there is a record of an increase in the short term events such as marine heat waves along the UK coastal regions lately(MCCIP, 2020).

Central England Temperature has risen by 0.9-1o C since 1980. All ten of the warmest years on record in the UK have occurred since 1990. Over the last three decades the UK seas have shown a pattern or increasing temperatures continuously(MCCIP, 2020). 2014 has been demarcated as the warmest year on the record and furthermore 8 of the ten warmest records are found after the year 2000(Dawson, 2015; MCCIP, 2020). Amidst the surrounding coastal lines, the North Scotland sea is recorded to have the most increase which records and increase of 0.24°C per decade(MCCIP, 2020).

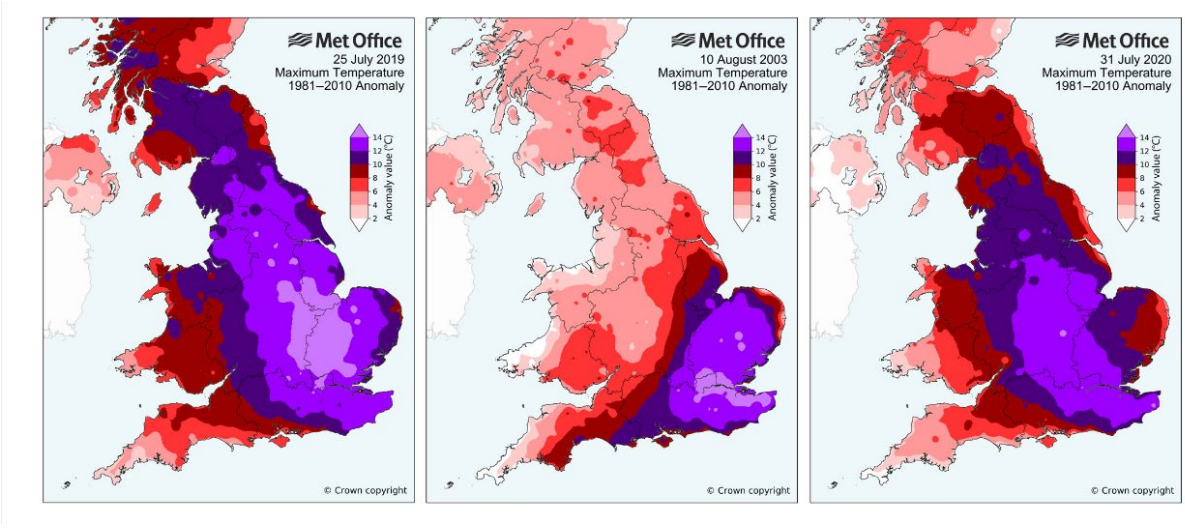

Figure 3:Daily maximum temperature anomalies relative to the 1981–2010 July average for the UK's three hottest days on record:25 July 2019, 10 August 2003, and 31 July 2020

In the coastal areas in the UK high warm temperatures are expected along with the sea level rise almost by more than 1m in many areas and the increased greenhouse emissions(Bob & Georgina, 2021). The figure presents the annual UK regional sea-surface temperature (ºc) anomaly for period 1950-2018.

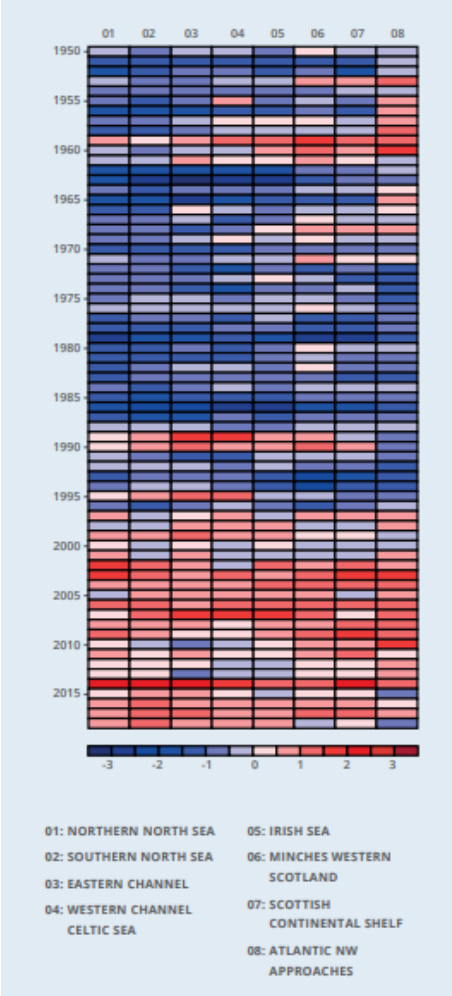

Figure 4:Sea-surface temperature anomaly (°C) for the period 1950-2018, relative to the 1981-2010 average.

Red = positive (warm); Blue = negative (cool).

4 Disaster Risk and climate change

The UK is affected by natural hazards, such as flooding, heatwaves and wildfires, which can cause significant human, economic, environmental and infrastructure damage(Stock & Wentworth, 2020). In this section how the climate change has affected disaster risk the coastal regions are to be discussed in detail under the main topics of hazard, vulnerability, and exposure.

In the UK context it is recorded that salt marshes reduced wave height by almost 61%, and total wave energy by an average of 82% (Spalding et al., 2014).

4.1 Hazard

Recently, there has been growing concern about escalating sea levels, and their influence on storminess, to increase the likelihood of coastal flooding around the world. According to the latest studies in 2020 the upper level of the sea level rise in the UK is much far than the anticipated rates which implies an increased risk of coastal floods. The magnitude and severity of the coastal floods are further exacerbated by the tidal changes and rainfall increase due to climate change(MCCIP, 2020).

Figure 5:A Flood in Looe, Cornwall.

In the years of 2013 and 2014 extreme storms and coastal floods caused around 2.5 billion damages in the UK. Furthermore, it has recorded the highest precipitation levels and wind speeds for the last 143 years. In terms of flood risk, according to estimates from the Environment Agency for England and

Wales, the Department of Agriculture and Rural Development for Northern Ireland, and the Scottish Environment Protection Agency (SEPA), there are approximately 3.1 million properties across the UK (2.6 million properties in England, 357,000 properties in Wales, 46,000 properties in Northern Ireland and nearly 100,000 properties in Scotland) that are at direct risk of flooding from rivers or the sea.

Another severe impact on the UK coastal line due to climate change impacts is the coastal erosion. At present, it has been estimated that some 17% of the coastline in the UK as a whole is suffering from erosion, with 30% in England, 23% in Wales, 20% in Northern Ireland and 7% in Scotland affected(Zsamboky et al., 2011). The geology of the UK is important in considering the potential effects of coastal erosion. The older and more resistant rocks are located in Northwest England, Wales, Scotland, and Northern Ireland. The coastlines of these areas are therefore the most resistant to erosion. Younger sedimentary rocks are less resistant, and areas of glacial sediments are particularly prone to erosion. These areas include the east, southeast and south of England(Zsamboky et al., 2011).

Figure 6:a road collapsing into the ocean at Skipsea Cliff, near Hornsea, in the East Riding of Yorkshire

4.2 Vulnerability

Coastal communities tend to rely on coastal ecosystems, seasonal employment related to high levels of tourism and other transient groups (students), infrastructure and communications, resulting in higher levels of vulnerability to major hazard such as, coastal erosion, coastal flooding, and sea-level rise impacts (Benzie 2014). Added to this, coastal floods can lead to differential levels of impacts (e.g., loss of life, damage to the built and natural environments or extreme disruption to the lives of the population affected) on coastal communities due to varying extents of local vulnerability (physical and socio-economic). Coastal zones are socially, economically, and environmentally important. They attract economic activity and settlements that lead to urbanisation, extension of infrastructure and other land use changes, ultimately resulting in further increases in flood vulnerability of coastal communities over time(Percival & Teeuw, 2019).

Coastal communities are likely to experience a series of challenges in relation to their ability to adapt to climate change. In the context of the UK many coastal communities also face a series of important socio-economic challenges including: ageing populations, youth outmigration and inward migration of older people, high proportions of retirees and people receiving benefits, transitory populations, physical isolation, poor-quality housing, an overreliance on tourism, seasonal employment, low income and pressure on services during the summer months (CCA, 2010; CLG, 2007; Centre for Rural Economy, 2006)(Mary Zsamboky, Amalia Fernández-Bilbao, David Smith, & Allan, 2011).

Many UK coastal areas already face deprivation and related socio-economic challenges that make them particularly vulnerable to the impacts of climate change (for example, owing to the economic decline of former seaside resorts and associated impacts on unemployment and social well-being)(Zsamboky et al., 2011). Residents may lack the economic resources to be able to make structural changes to their homes (e.g., to make them flood resilient) or may not wish or be able to afford to move away. Likewise, along with the climate risks along the coastal lines the inherent vulnerabilities of the resident populations increase the disaster risk due to climate change impacts.

4.3 Exposure

The coastal communities are exposed to significant threats due to seal level rise and other coastal hazards mainly because not only their residence but also their economic and social activities are concentrated around the coast(Zsamboky et al., 2011).

Coastal local authorities that contain areas are less likely to be able to afford or prioritise undertaking adaptation activities due to their lack of affordability. In addition, local authorities in coastal areas may have other issues that need attention and funding, such as regeneration and housing needs, which means that there are limited resources to be spent on climate change adaptation. The lack of effective

communication of climate change impacts leads to low levels of awareness and understanding of the risk in communities and also low levels of preparedness for the impacts(Zsamboky et al., 2011).As aforementioned UK's coastline is comprised of 10 km long stretches that are below 5 m elevation and at present, 414,000 people are exposed to sea level rise in the UK (CCA, 2021).One of the most dangerous challenges to settlements in the UK comes from flooding(Percival & Teeuw, 2019).In the UK, the UK Climate Change Risk Assessment (UKCCRA) has identified flooding as the greatest risk posed by a changing climate. Currently, some 5.2 million properties in England and Wales are at risk of flooding (Environment Agency 2017), and less than 10% of those 5.2 million are aware of it (Percival & Teeuw, 2019).

5 Climate change Impact in coastal regions

There is growing consensus that the populations, infrastructure and ecology of cities are at risk from the impacts of climate change(Wilby, 2007) . Climate change is reported to have both direct and indirect impacts on the coastal regions. In this classification the direct impacts are identified as accelerated coastal erosion and more powerful and frequent storm surges and indirect impacts are classified to be the physical and socio-economic impacts associated with the loss of critical physical infrastructure and coastal resources such as aquaculture, as well as declines in associated economic, ecological, cultural and subsistence values(Mary Zsamboky, Amalia, Fernández-Bilbao, David Smith, & Allan, 2011). In this study the climate change impacts in the coastal regions are identified under the themes physical, environmental, economic, and social.

5.1 Physical impacts

Sea level rise causes impact on coastal infrastructure assets. Coastal infrastructure refers to infrastructure located within the coastal zone, mostly infrastructure within 10m of mean sea level (Robert J Nicholls & Kebede, 2011). In the UK some urban areas and their infrastructure are already below average high-water levels(Dawson, 2015). By the 2080s, up to 1.5 million properties inclusive of 1.2 million residential infrastructure may be in areas with a 0.5% of greater annual level of flood risk and over 100,000 properties may be at risk from coastal erosion(CCC, 2018). The following table demonstrates a summary of coastal assets at risk from present day flooding in England.

Table 1: A summary of coastal assets at risk from present day flooding in England (Source: Jacobs (2018) Research to assess the economics of coastal change management in England and to determine)

Asset Category	**Flood Zone 2 (0.1% or greater risk of flooding per year)**	**Flood Zone 3(0.1% or greater risk of flooding per year)**
Residential properties	445,000	374,000
Non-residential properties	173,000	145,000
Motorways and A-roads (km)	930	770
All other public roads (km)	6,550	5,720
Railway lines (km)	552	436
Railway stations	77	59
Historic Landfill (ha)	3,370	2,500
Grade 1,2 and 3a agriculture land (ha)	205,000	187,000
Site of special scientific Interest (ha)	108,000	105,000

Coastal flooding and coastal erosion have placed the coastal properties, roads, ports, and railways at considerable risk. The UK vulnerability coastal erosion is indicated by the fact that it has around 2300 km of artificially protected coast, the longest in Europe. Alongside sea level rise has also increased coastal erosion in East England. Annual damages due to coastal erosion are expected to increase by 3-9 times, costing up to £126 million per year by the 2080s (Stock & Wentworth, 2020). In addition, approximately 1,600 km of major roads, 650 km of railway line, 92 railway stations and 55 historic landfill sites are at risk of coastal flooding or erosion by the end of the century. A further 100,000 properties located on complex cliffs could be at risk from coastal land sliding (CCC, 2018). Thames's estuary is a densely populated area where a large number of critical infrastructures exposed to the coastal climate change impacts(Bob & Georgina, 2021). An increase in the risk of riverine and coastal flooding and erosion; increased pressure on drainage systems; a potential increase in winter storm damage and increased risk of subsidence in subsidence prone areas (Gawith, 2005).

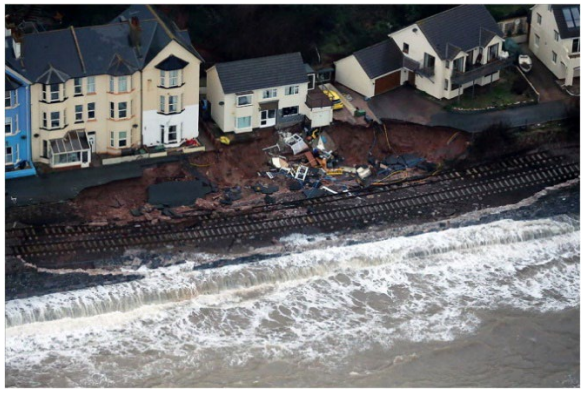

Figure 7: Sea-level rise impacts on transport infrastructure: The notorious case of the coastal railway line at Dawlish, England

Furthermore, the extreme events associated with the climate change will disrupt the functionality and service provision of critical infrastructure such as health and emergency services, transportation(Mary Zsamboky, Amalia, et al., 2011). Extreme events such as storms and flooding associated with climate change are also likely to affect key public infrastructure such as health and emergency services and public transport along the coast. For coastal areas that are already isolated, impacts on transport and key infrastructure could be particularly serious(Zsamboky et al., 2011). Many UK coastal areas are already characterised by their physical isolation, sometimes exacerbated by limited access by rail services or other public transport. A lack of access to public services, such as health and emergency services, can also be a problem(Zsamboky et al., 2011). The figure below demonstrates how the road infrastructure has been destroyed by the coastal erosion and rising sea levels in Happisburgh, Norfolk.

Figure 8:The end of the road in Happisburgh, Norfolk, where washouts swept away a coastal street

Climate change can exacerbate the natural rates of decay causing degradation of building structures and building materials. Physical impacts of sea-level rise include inundation and displacement of wetlands and lowlands, and increased flooding during coastal storms. As sea levels rise, without adaptation land is flooded more and more frequently and hence is usually degraded in terms of its current use, although this change may have benefits to other uses. Inundation is the ultimate endpoint of this process and will generally only occur when a coastal defence is abandoned as part of managed, or unmanaged, retreat(R. J. Nicholls et al., 2021). Furthermore, these damaging impacts have already been observed at a range of national heritage assets(MCCIP, 2020). A range of heritage sites located along the UK coasts are subjected to increased erosions, inundation, weathering and decay(MCCIP, 2020). Furthermore, risk assessments show that many coastal heritage assets managed by English Heritage and Historic Environment Scotland are currently at risk from coastal erosion and flooding, with climate change increasing this risk (MCCIP, 2020).

Another major impact of climate change on the physical infrastructure is the change in energy consumption In London the typical air-conditioned office building is estimated to increase energy used for cooling by 10% by the 2050s, and around 20% by the 2080s (Hunt & Watkiss, 2011). It has projected that climate change impacts will further increase thermal discomfort in buildings and health problems in summer (Gawith, 2005). These implications will demand physically preventive structures as well as more environmentally friendly and adaptive built environment structures. For example, since the 1970s there has been an increase in storminess and wave heights around Britain and this has caused a re-evaluation of the design standards required for sea and coastal defence and also contributed to saltmarsh decline(R. J. Nicholls et al., 2021).

5.2 Environmental Impacts

There is a significant impact on the coastal habitats in the UK due to the climate change impacts. Damages to ecosystems, salt marshes, mangrove forests, seagrass beds, soft sediments, kelp forests, coral reefs, and oyster reefs are some of the environmental impacts in the UK. The oxygen concentrations in the UK marine water is observed to far above the global average(MCCIP, 2020). Furthermore the temperature of the UK sea water is rising(MCCIP, 2020). The impacts on the marine eco systems are said to have multiplier effects on the food webs, seabed dwelling species as well as plankton, fish, birds and mammals in coastal regions(MCCIP, 2020).

From 1990 to 2012 there has been a 30% of a reduction in dune slack(MCCIP, 2020). The total extent of salt marshes also has reduced due to erosion and coastal squeeze. The coastal squeeze is the reduction of the coastal beaches due to hard physical built structures(MCCIP, 2020). Erosion is also expected to increase, partly because of sea level rise. Parts of the coast that are composed of low-lying and soft sediment will be most vulnerable specially in the east of England because they are most easily eroded.

The most exposed locations and estuaries may be particularly vulnerable to the disaster risk in coastal regions (Zsamboky et al., 2011). These locations experience significant impact on the coastal biodiversity as well. In the United Kingdom, for example, large areas of intertidal habitat have been lost due to land claims for industrial development and agriculture. This is now being exacerbated by inundation due to coastal squeeze, in which intertidal habitat is constrained by the sea on one side and defensive walls on the other; this is having negative impacts on the characteristic biodiversity of the intertidal zone (MacDonald et al., 2020).

Furthermore, climate change implications include decreased productivity, diversity, and resilience of nearshore marine ecosystems. There have been no major changes or geographical shifts in species farmed in the UK due to climate change. However, increasing problems with invasive species, fish gill diseases, viruses and Vibrio contamination of shellfish are being linked with a changed climate(MCCIP, 2020). The impacts of climate change are further exacerbated by the environmental pollution which has negative consequences on the surface, ground and drinking water quality, aquatic, and terrestrial ecosystem function(Gawith, 2005). These conditions will necessitate the environmental restoration after a disaster.

5.3 Economic Impacts

A major economic impact is the losses due to damages in the coastal infrastructure. The impacts of such hazards can be wide-ranging but may include disruption to critical infrastructure and transport networks, detrimental effects on human welfare, and, in some cases, loss of life. In terms of the economic losses recent events include winter flooding in 2015–2016 that cost the UK economy approximately £1.6 billion,1 and the 2010 eruption of the Icelandic Eyjafjallajökull volcano, which resulted in restrictions on UK airspace for several weeks, stranding travellers around the world(Stock & Wentworth, 2020).

Coastal erosion, flooding, sea-level rise and potential changes in storminess present multiple risks to UK industries and coastal communities(MCCIP, 2020). A wide range of economically important marine and coastal industries are being affected by climate change, with impacts on food availability, infrastructure, seasonal operating windows, and the movement of goods. Climate change will pose risks and challenges both for people, and for coastal economies and local industry such as fisheries, agriculture and tourism(Zsamboky et al., 2011).

Commercial fishing is an important socio-economic activity in coastal regions in the UK (Cheung et al., 2012). The productivity of the fisheries industry in the UK has been negatively affected by the ocean warming and historical overexploitation(MCCIP, 2020). Furthermore, the UK coastal regions being populated with ocean-dependent communities and businesses are exposed to the inherent climate risk the finite resources are at risk. Effects of climate and ocean changes driven by greenhouse gas emission on marine fisheries has direct impacts on the resource availability, fishing operations, fisheries management and conservation measures, as well as the bottom line of the fisheries industry(Cheung et al., 2012).

These situations create loss of coastal income and economic depression. It may also affect people's access to, and the quality of, basic goods and services such as water, food, health, and emergency care. The costs of emergency action, prevention and recovery may be a significant burden to coastal communities affected. As a large proportion of the costs often falling on local authorities in areas with already limited resources it will become a burden to the local economies(Zsamboky et al., 2011).

Impact on marine-based industries such as tourism, fisheries, aquaculture are frequently seen in the coastal regions. Additionally, these circumstances will have an impact on the employment status of the coastal communities. Climate change impacts will have important implications for the UK commercial fishing industry as a livelihood, for the local economy and in terms of providing a large proportion of jobs (Zsamboky et al., 2011). By 2050, under a high-emissions scenario, the total maximum fisheries catch potential is projected to decrease within the UK Exclusive Economic Zone (EEZ), resulting in a 10% decrease in net present value(MCCIP, 2020).

Change in climatic conditions will reduce the potential catch of species with northern distributions, such as cod and plaice because of a shift in distribution and changes in stock productivity. On the other hand, some evidence suggests that warm-water species are moving into UK and Irish seas and offer new fishing opportunities, although detailed scientific analysis is lacking(Cheung et al., 2012) .

There will be impact on planning economic development due to climate change consequences in coastal regions. The climate change impacts has resulted in reduction of housing values, developments and investment(Mary Zsamboky, Amalia Fernández-Bilbao, et al., 2011). Furthermore, climate change also presents risks to human health and wellbeing, such as physical impacts through flooding and disease and wider sociocultural effects such as the loss of heritage sites and changes in tourism and recreation. Climate change impacts on industry and society and their responses to these drivers is modulated by wider external factors such as government policies, economic fluctuations, demographic changes and societal values(MCCIP, 2020).

On the other side there can be some short-term beneficial situations to the UK coastline as a result of the climate change impacts. Warmer summers are predicted to result in more comfortable conditions at the coast, extended tourism seasons, increased revenues, new infrastructure, and increased employment and water-sport opportunities(MCCIP, 2020). Possible benefits to UK coastal tourism due to rising temperatures(Robert J Nicholls & Kebede, 2011).However in the long run it will again have damaging consequences on the some coastal communities and infrastructure (MCCIP, 2020). There are direct and indirect impacts on the UK finance, business, and insurance industry. Coastal infrastructure will often be insured in the UK so coastal losses will fall on UK markets(Robert J Nicholls & Kebede, 2011). The coastal communities and their livelihoods are endangered which has made it difficult for in sourcing insurance schemes for these areas as well.

5.4 Social Impacts

Decreased agricultural and livestock productivity is one of the climate change impacts seen in the UK coastal regions. Agriculture is a key industry in many districts along the UK coast. Climate changes including increased variability of temperature and precipitation could negatively affect UK agriculture (DEFRA, 2005b). Weeds, pests, and diseases are likely to expand their range as temperatures rise, and farmers may struggle to adapt to changing climate conditions. A mounting issue in the agricultural sector is the increased incidence of saltwater intrusion in irrigation systems. This is due to coastal storm surges and results in soil degradation and lower crop yields. For hotspot areas such as Yorkshire and Lincolnshire and East Anglia, where there is a predicted rise in temperature and lower precipitation levels, this could put additional pressure on freshwater availability to local farmers,

creating a compounding effect which could have serious consequences for sustained agricultural production in these areas.

Furthermore, climate change will impact coastal livelihoods, affecting in particular those depending on the coast for their economic activities and livelihoods(Zsamboky et al., 2011). Climate change impacts can also lead to longer-term effects on neighbourhoods. For instance, areas that suffer the impacts of climate change or are considered to be at high risk may be affected by blight and a reduction in housing values, development, and investment. In addition, homes located in areas at risk of coastal erosion and landslip may become uninhabitable. Longer term there will be issues about how housing markets respond to changes in risk affecting households in coastal and other areas due to climate change(Zsamboky et al., 2011).

There are increased human health risks identified due to climate change in the coastal regions.

Climate change will affect people's health in particular, because of the effects of an increase in extreme events such as flooding and heatwaves. The focus on the health effects in both cities reflects increased concerns from the risk of heat extremes and potential exacerbation by urban heat island effects (Hunt & Watkiss, 2011). Furthermore, Climate change will affect future health outcomes directly through extreme weather events such as heat waves, cold spells, and flooding impacting on the built infrastructure and social and institutional systems of health care provision, and indirectly due to induced changes in the volume and structure of demand for health care(Paavola, 2017). Those who have pre-existing health problems or are very elderly are likely to be worst affected. Mental health impacts are particularly prevalent the affected communities due to loss of neighbourhood and human migration (Zsamboky et al., 2011).

In such circumstances the need of Social Protection programmes is developed. It is likely that self-protection actions at the household level would not be practical for extreme events such as tidal surges or severe storms(Zsamboky et al., 2011).Furthermore, many vulnerable coastal communities and the local authorities in which they live may need high levels of support from central government if they are to successfully adapt to a changing climate and reduce the risks from climate impacts(Zsamboky et al., 2011). This should be a policy priority and the vulnerability of these communities should be considered in the ongoing UK climate change risk assessment(Zsamboky et al., 2011).

6 Climate change impact on built environment in coastal regions

As discussed in the previous sections, current predictions for the UK suggest that both temperature and sea level are rising. Many of England's coastal defences are likely to be at risk of failure as sea levels rise. For example, a sea-level rise of 0.5 m is predicted to make a further 20% of England's coastal defences vulnerable to failure(CCC, 2018). Global trends in sea-level rise affect the UK, particularly along the Norfolk and Suffolk coastlines in southeast England, where data exhibits a rising trend throughout history(Kantamaneni, 2016). Popular holiday destinations and vital roads in the UK could be wiped out by floods due to climate change, experts warn. Coastal and low-lying areas vulnerable to flooding could be completely submerged in water in thirty years' time if action is not taken. Parts of North Wales and eastern England are likely to be under water by 2050 due to rising sea levels, which could wash away railways and swamp farmland and holiday resorts. In the south, coastal areas and river valleys would be badly affected with the M4 motorway submerged close to the Severn Bridge (Cathy Owen, 22 Jun 2021). The increased rainfall, as well as rising sea levels, means there could be as many as one million homes with a high risk of flooding by 2050. While a significant investment of £2.5 billion is set for flood defences between 2015-2021, most will be coastal flooding. (CCC, 2018). Around £150 billion of assets in the UK are at risk from coastal flooding and damages to the UK from coastal flooding are estimated to be of the order of £500 million per year (Howard & Palmer, 2020). The 2007 summer floods affected 55,000 properties and were estimated to cost £3.2 billion, while the 2013–2014 floods cost approximately £1.3 billion in insurance claims. In December 2015, during Storm Desmond, wind gusts of up to 81 mph and record-breaking volumes of rainfall were recorded across Northwest England. The storm, and its associated rainfall, is estimated to have flooded 8900 properties with over 100,000 properties left without power , with costs estimated at £1.3 billion(Hemingway & Gunawan, 2018).

The M4 motorway submerged close to the Severn Bridge would badly affect coastal areas and river valleys in the south. (Cathy Owen, 22 Jun 2021). A recent study by the Chartered Institute of Building Services Engineers (CIBSE) modelled a range of impacts on building design and operation by examining changes to average and extreme temperature and humidity levels up to the 2080s (CIBSE, 2004). Many older buildings, traditionally constructed in heavy materials, with small windows and good ventilation (both controlled and uncontrolled), have performed well during recent heatwaves. But many late-20th-century buildings are constructed by lightweight, poorly insulated construction, large expanses of unshaded glazing and poor ventilation in summer(Gething & Puckett, 2019). As a result, coastal infrastructure is likely to be unviable in its current form in the future, which needs urgent adaptation and climate change response plans throughout the coastal regions.

In a badly designed building, internal temperatures can be greater than external ones, so these findings may be an underestimate of the impact of warmer conditions. The number of hours when the external temperature exceeds 25°C (when there is some discomfort) may also treble in London by the 2080s Medium High Emissions scenario, indicating an acute risk of summer overheating. The rate and magnitude of adaptation required across the country is expected to vary considerably. By the 2080s, peak temperatures in Manchester will be similar to those of the 1980s in London. Similarly, the 2080s peak temperatures in Edinburgh will equate to those of the 1980s in Manchester. Accordingly, over the last decade, the UK has experienced a number of severe natural hazard events that have had large economic and human impacts on communities, properties, and infrastructure networks. Amidst those the coastal regions and the associated built environment has experienced severe implications which needs strong climate change adaptation plans.

7 Conclusion

Disasters and disaster risks are on the rise worldwide. The trend is expected to continue as climate change increases the frequency and severity of extreme weather events. The study was conducted at two different levels. A global review was conducted based on a systematic literature review, and parallelly induvial country-level studies were conducted based on the partner countries. The study was farmed around four primary research questions; the evidence of climate change in coastal regions, the disaster risks associated with climate change in coastal regions, the impact of climate change in coastal regions and the impact of climate change on the built environment in coastal regions. The primary climate change evidence in the coastal regions is the sea-level rise, changing weather conditions and precipitation changes. Then the associated natural hazards due to this climate change evidence were highlighted as coastal erosion, inundation, extreme weather events and flooding. Under each of these hazard categories, their impact on the coastal regions was summarised through the findings.

8 References

Bob, W., & Georgina, K. (2021). How is climate change affecting coastal flooding in the UK? Retrieved from https://www.lse.ac.uk/granthaminstitute/explainers/how-is-climate-change-affecting-coastal-flooding-in-the-uk/

Cathy Owen, N. A. (22 Jun 2021). New map of UK in 2050 predicts British seasides vanishing as parts submerged under water. Retrieved from https://www.mirror.co.uk/news/uk-news/parts-uk-could-completely-submerged-24370412?utm_source=linkCopy&utm_medium=social&utm_campaign=sharebar

CCA. (2021). Coastal flood risk United Kingdom.

CCC. (2018). *Managing the coast in a changing climate*. Retrieved from

Cheung, W. W., Pinnegar, J., Merino, G., Jones, M. C., Barange, M. J. A. C. M., & Ecosystems, F. (2012). Review of climate change impacts on marine fisheries in the UK and Ireland. *22*(3), 368-388.

Chini, N., Stansby, P., Leake, J., Wolf, J., Roberts-Jones, J., & Lowe, J. J. C. E. (2010). The impact of sea level rise and climate change on inshore wave climate: A case study for East Anglia (UK). *57*(11-12), 973-984.

Dale, M. J. P. T. o. t. R. S. A. (2021). Managing the effects of extreme sub-daily rainfall and flash floods—a practitioner's perspective. *379*(2195), 20190550.

Dawson, R. (2015). *A Climate Change Report Card for Infrastructure*. Retrieved from

de la Vega-Leinert, A. C., & Nicholls, R. J. J. J. o. C. R. (2008). Potential implications of sea-level rise for Great Britain. *24*(2), 342-357.

Gawith, C. W. M. (2005). *Measuring progress Preparing for climate change through the UK Climate Impacts Programme*. Retrieved from Oxford:

Gehrels, R., & Long, A. J. G. (2008). Sea level is not level: the case for a new approach to predicting UK sea-level rise. *93*(1), 11-16.

Gething, B., & Puckett, K. (2019). *Design for climate change*: RIBA publishing.

Hemingway, R., & Gunawan, O. J. I. j. o. d. r. r. (2018). The Natural Hazards Partnership: A public-sector collaboration across the UK for natural hazard disaster risk reduction. *27*, 499-511.

Hossain, M. S., Qian, L., Arshad, M., Shahid, S., Fahad, S., & Akhter, J. (2019). Climate change and crop farming in Bangladesh: an analysis of economic impacts. *International Journal of Climate Change Strategies and Management, 11*(3), 424-440. doi:10.1108/IJCCSM-04-2018-0030

Howard, T., & Palmer, M. D. J. E. R. C. (2020). Sea-level rise allowances for the UK. *2*(3), 035003.

Hunt, A., & Watkiss, P. J. C. c. (2011). Climate change impacts and adaptation in cities: a review of the literature. *104*(1), 13-49.

Kantamaneni, K. (2016). Coastal infrastructure vulnerability: an integrated assessment model. *Natural Hazards, 84*(1), 139-154. doi:10.1007/s11069-016-2413-y

MacDonald, M. A., de Ruyck, C., Field, R. H., Bedford, A., Bradbury, R. B. J. E., Coastal, & Science, S. (2020). Benefits of coastal managed realignment for society: Evidence from ecosystem service assessments in two UK regions. *244*, 105609.

Mary Zsamboky, Amalia, Fernández-Bilbao, David Smith, & Allan, J. K. J. (2011). *Impacts of climate change on disadvantaged UK coastal communities*. Retrieved from

Mary Zsamboky, Amalia Fernández-Bilbao, David Smith, J. K., & Allan, a. J. (2011). *Impacts of climate change on disadvantaged UK coastal communities* Retrieved from

MCCIP. (2020). *Marine Climate Change Impacts: Marine Climate Change Impacts Report Card 2020*. Retrieved from

Nicholls, R. J., Hanson, S. E., Lowe, J. A., Slangen, A. B. A., Wahl, T., Hinkel, J., & Long, A. J. (2021). Integrating new sea-level scenarios into coastal risk and adaptation assessments: An ongoing process. *Wiley Interdisciplinary Reviews: Climate Change, 12*(3). doi:10.1002/wcc.706

Nicholls, R. J., & Kebede, A. (2011). The implications on the UK of the impacts of climate change and sea-level rise on critical coastal infrastructure overseas, 2010 to 2100.

Paavola, J. J. E. H. (2017). Health impacts of climate change and health and social inequalities in the UK. *16*(1), 61-68.

Percival, S., & Teeuw, R. J. N. H. (2019). A methodology for urban micro-scale coastal flood vulnerability and risk assessment and mapping. *97*(1), 355-377.

Poo, M. C.-P., Yang, Z., Dimitriu, D., Qu, Z., Jin, Z., & Feng, X. (2021). Climate Change Risk Indicators (CCRI) for seaports in the United Kingdom. *Ocean & Coastal Management, 205*, 105580. doi:https://doi.org/10.1016/j.ocecoaman.2021.105580

Smith, K. (2013). *Environmental hazards: Assessing risk and reducing disaster*.

Spalding, M. D., Ruffo, S., Lacambra, C., Meliane, I., Hale, L. Z., Shepard, C. C., & Beck, M. W. (2014). The role of ecosystems in coastal protection: Adapting to climate change and coastal hazards. *Ocean & Coastal Management, 90*, 50-57. doi:https://doi.org/10.1016/j.ocecoaman.2013.09.007

Stock, M. J., & Wentworth, J. (2020). Evaluating UK natural hazards: the national risk assessment.

Wilby, R. L. (2007). A Review of Climate Change Impacts on the Built Environment. *Built Environment (1978-), 33*(1), 31-45.

Zsamboky, M., Fernández-Bilbao, A., Smith, D., & Wilson, S. (2011). *Impacts of climate change on disadvantaged UK coastal communities*.