CASE STUDY

Climate Change and European Coast and Beach Management

ABSTRACT
Climate change is one factor affecting coast and beach management. The biggest impacts for coastal and beach management remain local human uses and developments, and not global anthropogenic climate change. However, climate change has and will cause additional and unforeseeable impacts for coastal and beach management within Europe, and particularly in regions of the Mediterranean Sea and south Atlantic Ocean.

LOCATION
Watersheds, coastal and marine areas of Europe, Mediterranean Sea, south Atlantic Ocean

KEYWORDS
Climate change, water quality, pollution, nature conservation, fisheries and aquaculture, development pressures, economics, governance, recreation and tourism, stakeholder and public participation, beach and coastal management, zoning

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EXECUTIVE SUMMARY

Climate change is one factor but not the only factor affecting European coast and beach management. Human uses and developments have the biggest impacts on coastal and beach management, and not anthropogenic climate change. However, climate change has and will cause additional and unforeseeable impacts for coastal and beach management.

Climate change is a global phenomena with differing local and regional manifestations throughout Europe. Depending on the region and local vulnerabilities and resilience, coastal and marine ecosystems will respond in different ways to the interrelated issues of human uses and developments and climatic change.

One of the greatest global issues and challenge is the increasing acidification of the oceans, and how this acidification will impact coastal and marine ecosystems. Biodiversity, conservation, water quality, quantity and seasonal flows will be significantly affected by climate change. The impacts of pollution and nutrient influxes into waters may increase as a result of climate change. Depending on the local characteristics, erosion, sediment deposition, drought, desertification and flooding may intensify or shift.

Climate impacts on the watersheds, coastal and marine areas of Europe are considered. The Mediterranean Sea, and south Atlantic Ocean are specifically focused upon due to the greater and more extreme impacts they have and will experience.

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Climate Change and Coast and Beach Management in Europe[1]

Introduction

Climate change is one factor, but not the only factor affecting coastal and beach management. Human uses and developments have the biggest impacts on coastal and beach management in Europe, and not anthropogenic climate change. However, climate change has and will cause additional and perhaps unforeseeable impacts for coastal and beach management. Different aspects of these changes are highlighted here, including overall nature of climate change and acidification. There is then a discussion of biodiversity, conservation and fisheries. This is followed by a discussion of impacts on fresh water and coastal waters within Europe, including impacts on water quality and quantity, eutrophication, and drought, desertification and flooding. There is then as discussion of sea level rise, extreme weather events and erosion. Finally there is an overview of impacts for sustainable tourism, particularly in the Mediterranean and south Atlantic, and suggested coast and beach management approaches for climate change.

Global change and regional and local implications

Climate change is a global phenomena, with differing local and regional manifestations throughout Europe. The watersheds, coasts and marine areas of Europe, and more specifically the Mediterranean Sea, and south Atlantic Ocean are focused upon here, but all regions of the world are being impacted. The polar and equatorial regions are experiencing the earliest and greatest impacts. Small island states and less developed continents as Africa, Caribbean and Latin America are also vulnerable to change and will experience difficulties in adapting. Depending on the region, watershed and sea, and local vulnerabilities and resilience, coastal and marine ecosystems will respond in different ways to the combination of human uses and developments and climatic change.[2]

The Third Global Conference on Oceans, Coasts and Islands took place in Paris from January 23 to 28, 2006, and included a panel on oceans and climate issues. Oceans and climate issues were recognized and the panel recommended follow-up

[1] Copyright Magdalena A K Muir 2006. Magdalena A K Muir is a Research Associate, Arctic Institute of North America, and Advisory Board Member, Climate Change, EUCC- The Coastal Union, an European coastal non-governmental organization. She is also President and Associate with International Energy, Environmental and Legal Services Ltd. Her email address is makmuir@ieels.com.

[2] Up in smoke? Latin America and the Caribbean: The threat from climate change to the environment and human development. This third report is from the Working Group on Climate Change and Development, a coalition of 20 major environment and development groups. There is also an earlier report, "Africa-Up in Smoke", a recent report by the UK Working Group on Climate Change and Development, available by same group at http://www.oxfam.org.uk/what_we_do/issues/climate_change/africa_up_in_smoke.htm.

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measures. A panel summary was drafted that included recommendations arising from the panel presentations and subsequent discussion. This summary and the recommendations are discussed in detail below.[3] Recognition and recommendations on oceans and climate issues are important due to the need for global mitigative measures, as well as global, regional, and local adaptive measures. These measures are needed to address and minimize climate impacts on coasts and oceans and coastal and marine ecosystems, and the environmental and economic goods and services these ecosystems provide

The panel summary began with a discussion of the Intergovernmental Panel on Climate Change (IPCC), which will presents the Fourth Assessment Report to the 13th Conference of the Parties to the United Nations Framework Convention on Climate Change in December 2007. This report and prior IPCC reports document the impacts of man-made climate change, and the most vulnerable populations and economic sectors that have immediate and long-term adaptations for climate change.

Some of the key vulnerabilities are for oceans, coasts and islands. The panel summary indicated that sea level rise is a significant threat for small islands, coasts and low lying lands. Ocean acidification is a new and looming threat that could undermine the marine food web, and preclude coral development. Sea level rise and acidification will remain for the next few thousand years. Another emerging and more immediate threat is the impact of high sea surface temperatures on the intensity of tropical cyclones and hurricanes. Understanding of the role of oceans as a regulator of the earth's climate system is also increasing. The oceans control the timing and magnitude of changes in the global climate system, primarily through the absorption of carbon dioxide and heat. Other climate impacts include arctic sea ice reduction, cyclonic storms, changes in ocean circulation, and inter-related changes in biodiversity and fisheries.[4]

The Arctic Climate Impact Assessment Scientific Report documents climatic changes for the circumpolar Arctic. The Arctic has been warming rapidly and much larger changes are projected for the future.[5] Small islands are also vulnerable to the impacts of climate change, sea level rise and extreme events because of size and exposure to natural hazards, and more limited adaptive capacity. According to the Third Assessment Report of the IPCC, islands, like the Arctic, are early indicators of

[3] Climate and Oceans, Summary Prepared by Magdalena A.K. Muir, Research Associate, Arctic Institute of North America, Reports from the Third Global Conference on Oceans, Coasts and Islands, January 23 to 28, 2006, UNESCO, Paris. http://www.globaloceans.org/globalconferences/200s6/pdf/OutcomesClimate.pdf#search=%22magdalena%20muir%22. See also background paper, *Recent Developments at Global and Regional Levels of Relevance to Panel 11: Oceans and Climate*; article and panel presentation, *Monitoring and Managing for Climate Change in Vulnerable Oceans and Coastal Ecosystems, and Integrating Results into Policy Responses*, also prepared by the author for that meeting.

[4] Though it is not relied upon in this article, it is suggested that the reader refer to the website, www.realclimate.org for accurate and timely summaries of the impact of climate change on coasts and oceans.

[5] . Further and more extensive information on the Scientific Report, as well as links to chapters is available on the website of the Arctic Monitoring and Assessment Program (www.amap.no).

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global climate change. Islands often depend on rainwater, and are vulnerable to changes and distribution in rainfall.

The role of biodiversity and ecosystem services in supporting the provision of economic services is discussed and illustrated in the Millennium Ecosystem Assessment. This is also an emerging way of understanding the benefits of biodiversity, and the conservation of that biodiversity. Chapter 10: Principles of Conserving the Arctic's Biodiversity of the Arctic Climate Impact Scientific Assessment Report discusses how arctic biodiversity will be affected, and how management of conservation may have to change as ecosystems and species shift, and as common species become scarce and vice versa.[6]

Parallel changes are occurring, and parallel approaches will be required for small islands and similarly affected equatorial and tropical regions. Coral reefs, marine fisheries and marine resources will be affected by climate change and variability. Small islands with a large Exclusive Economic Zone already have limited capacity to manage that zone, and these management issues will be compounded by climate change. Subsistence and commercial agriculture on small islands will be impacted by sea level rise due to flooding, salt water intrusion into fresh water, salination of the soils, and declines in water quality and quantity. Infrastructure and developments in all regions will be affected by sea level rise and extreme events, which affects tourism, agriculture, transportation and the delivery of health, fresh water, food and other essential services.

In common with many parts of the equatorial and tropical world, human health is also impacted by climate change. For example, diarrhoea will increase with increases in temperature and deterioration of water in the Pacific. Vector-bourne diseases like dengue fever and malaria will increase, with the Caribbean islands being at greater risk. Shortages of water and drought, as well as contamination of water quality during floods and storms, will increase disease risk, including cholera, diarrhoea and dengue fever. [7]

Climate change is a global phenomena that will have differing local and regional manifestations throughout Europe, and the Mediterranean and south Atlantic region. Depending on the region and local vulnerabilities and resilience, coastal and marine ecosystems respond in different ways to the combination of human uses and developments and climatic change.

Climate change is one factor but not the only factor or, in most cases the primary factor affecting coastal and marine management. Human uses and developments have the biggest impacts on coasts and marine resources. However, climate change

[6] The Millennium Ecosystem Assessment is found under www.maweb.org/en/index.aspx. There is an extensive discussion of impacts of climate change and biodiversity in the Arctic under Usher M. et al., Chapter 10, Principles of Conserving the Arctic's Biodiversity, Arctic Climate Impact Assessment Scientific Report.

[7] These prior two paragraph are based on the summary of the Oceans and Climate panel, as well as the underlying expertise of the panel members and their presentations for that panel.

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has and will cause additional and unforeseeable impacts for coasts and marine resources. Along with other factors, climate change needs to be considered by businesses, local authorities and NGOs when planning sustainable tourist developments.

There is considerable research and practical projects currently underway examining impacts on climate change at a global and European level. For example, there is the European climate change and sustainable tourism initiative under the the European Network of Coastal Practioners, the UN-affliated World Tourism Association, and the Djerba Declaration on Tourism and Climate Change.[8]

Considering vulnerable European regions, the Mediterranean Sea is a largely enclosed sea, with high temperature and salinity, and decreasing fresh water due to dams and river diversions. Under the changing climate regime, sea surface temperatures and salinity will increase. Biodiversity, conservation, water quality, quantity and seasonal flows will be significantly affected. The negative impacts of pollution and nutrient into waters may increase. Depending on the local characteristics, erosion, sediment deposition, drought, desertification and flooding may intensify or shift.

Coastal and beach tourism is also an important source of income in the Mediterranean and south Atlantic regions. The ongoing economic viability of many regions and local communities will depend on an acceptable balance being tourist development and the maintenance of the coastal and marine ecosystems that tourism activity depends upon.

Acidification and other global issues

Ocean acidification is a new and looming threat that could undermine the marine food web, and preclude the coral development upon which much sustainable tourism depends. The dissolution of carbon dioxide in seawater leads to considerable acidification and changes to the geobiochemical carbonate balance. The oceans have absorbed one third of anthroprogenic CO2 emissions, which has caused significant acidification. These emissions affect the marine environment directly, in addition to any other impacts that occur due to climate change.

The continuation of current trends will lead to a level of acidification without precedent for several million years, and that will last for millenium. The effects on marine ecosystems cannot be forecast exactly. There is the risk of profound changes to the food web, as calcification of marine organisms may be precluded, or

[8] Climate change and sustainable tourism initiative under the the European Network of Coastal Practioners, http://www.coastalpractice.net; or UN affliated World Tourism Association (http://www.world-tourism.org), and the Djerba Declaration on Tourism and Climate Change, (http://www.world-tourism.org/sustainable/climate/decdjerba-eng.pdf)

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in some cases prevented. On a global level, there are parallels to problems with the acidification of lakes and rivers by acid rain that occurred in the 1970s and 1980s.[9]

Acidification, as well as sea level rise, will remain the next few thousand years. Sea level rise is one factor in water impacts and erosion, and is generally understood as a slower but predictable impact of climate change. Over time, sea level rise may change coastal, island and marine ecosystems, particularly if tourist development and transportation infrastructure prevents these ecosystems from moving inland. As well, sea level rise will affect fresh waters. One fresh water impact is increasing salt water intrusion in aquifers and estuaries, particularly depleted aquifers or subsiding estuaries.

Another emerging issues is the impact of high sea surface temperatures on the intensity of tropical cyclones and hurricanes. There is also an increasing understanding of the role of oceans as a regulator of the earth's climate system. The oceans control the timing and magnitude of changes in the global climate system, primarily through the absorption of carbon dioxide and heat. Other global climate impacts include arctic sea ice reduction, cyclonic storms, changes in ocean circulation, and changes in biodiversity and fisheries.

Biodiversity, conservation and fisheries

Principles of biodiversity conservation and climate impacts are considered in the Council of Europe paper, Conserving European Biodiversity in the Context of Climate Change.[10] This concern over the interaction between biodiversity and climate change was continued in the recommendations of the European Platform for Biodiversity Research Strategy, which were then introduced to a meeting of EU Nature Ministers in October 2005.[11] Interactions between biodiversity and climate change are also being considered for adaptation measures under second stage of the European Climate Change Programme.

Climate change, in combination with human uses and developments, affects coastal and marine biodiversity, and the coastal and marine ecosystems that provide vital ecosystems goods and services. These ecosystems goods and services underpin

[9] R. Schubert et al, German Advisory Council on Climate Change, The Future Oceans, Rising Up, Warming Up and Turning Sour, 2006. See also, Climate and Oceans, Summary Prepared by Magdalena A.K. Muir, Research Associate, Arctic Institute of North America, in Reports from the Third Global Conference on Oceans, Coasts and Islands, January 23 to 28, 2006, UNESCO, Paris. In 2005, the IPCC presented a special report on carbon dioxide sequestration. It found that storing captured carbon dioxide in geological formations is a mature technology. Ocean storage, or the direct release into the ocean water column or onto the deep seafloor, has been researched less. This storage option is less permanent than geological storage and significant uncertainty remains on ecosystem impacts, particularly the complication of increased acidification if releases occur.

[10] M. Usher, Conserving European Biodiversity in the Context of Climate Change (For Council of Europe. 2005). This paper has the same author as Chapter 10 of the Arctic Climate Impact Assessment Scientific Report, and is influenced by that earlier chapter.

[11] These recommendations are entitled Recommendations on Climate Change and Biodiversity Conservation: Knowledge Needed to Support Development of Integrated Adaptation Strategies (see www.epbrs.org).

sectors like fisheries, tourism, recreation, nature conservation and the varying needs of local communities, residents, and visitors.

Local, artisanal, sport and commercial fisheries will be affected by climate change. These impacts can include higher sea surface temperatures, stratification of the seas and alteration of the food web, which in turn can affect nutrients, spawning and growth of important fish species. As well, higher sea temperature can facilitate the introduction, and the emigration and immigration of valuable fish species. Climate change is already affecting on coastal and estuarine fisheries. For example, the UK State of the Seas of 2005 report discusses some of the changes occurring in the food web, which in turn affects fish populations. Due to shifting water temperatures, there have been shifts in fish populations in the North Sea, where fish stocks in the Norwegian and EC waters are moving to Icelandic waters. There are been parallel shifts in the Barents and Bering Sea.

Part of the dilemma for fish stocks are difficulties in separating climatic impacts, from impacts of overfishing and increasing destruction of coastal and estuarine habitat, which also need to be highlighted. This parallels the interaction between human uses and developments, and climatic impacts on coasts. There is also greater likelihood of the introduction and survival of invasive marine species in coastal and marine waters, which can affect the overall ecosystems and health and populations of these ecosystems and important fish species.

Complex interactions between overfishing and climate change could facilitate ecosystem shifts. A recent example may be presence of algal blooms and jellyfish in Mediterranean and other regions due to combination of higher water temperatures, overfishing and nutrient influxes. In the Mediterranean, algal blooms are boosted by nitrate and phosphate influxes from farming and human wastes. Jellyfish also benefit from the reduction in the number of natural predators like loggerhead turtles and the bluefin tuna, which have been drastically reduced by over-fishing. Once jellyfish are predominant, it can difficult for juvenile fish populations to re-establish that predator-prey relationship. Reduced river flows during hotter summers might also lead to increased numbers of jellyfish near the shore, as freshwater currents no longer keep the jellyfish offshore. The predominance of jellyfish and algal blooms in coastal waters and adjacent to beaches also reduces the attractiveness of tourism for those beaches.

Enclosed shallow seas such as the Mediterranean Sea, Baltic Sea and Black Sea are very vulnerable to warming and other climate changes. On a longer term basis, ecosystems shifts such as jellyfish and algal could be perceived as an indication that the Mediterranean Sea and region is under stress, and that the sea is becoming "tropicalised". The Mediterranean climate, typified by cool wet winters and dry hot summers, may be shifting with related impacts on terrestrial, coastal and marine ecosystems and biodiversity, and the economies and communities they support.

In complex ways, climate change can affect the ecological or carrying capacity of these natural ecosystems, which forms the overall basis for tourist developments in

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Europe and the Mediterranean and south Atlantic region. In order to allow these coastal and marine ecosystems to adapt to the climate changes that will occur, human stresses, including those caused by tourist developments, need to be reduced. Among other matters, this requires an integrative and ongoing ecosystem based approach to the planning of these tourist developments. Separate from these economic and conservation needs, coastal and marine ecosystems meet many needs for local communities such as food, transport, recreation, as well as providing cultural and historical links.

Water uses, and alterations in water quality and quantity

Water uses, and alterations in water quality and quantity, may be complemented and aggravated by seasonal shifts and changes in temperature and precipitation due to climate change. Many water uses in coastal communities, particularly water uses for tourism developments, are currently unsustainable. These water uses may reduce river flows and drain existing ground water aquifers. Climate change may further reduce these river flows, and impede the replenishment of these aquifers, even if more sustainable withdrawals are attempted. Additionally, salt water intrusion of these aquifers and estuaries will become an increasing risk as the sea level rises. This risk of saltwater intrusion is particularly great for groundwater aquifers on islands and coasts where these aquifers are already depleted.

Availability of water is already an issue in some tourist destinations. Water is already imported to some islands in the Mediterranean, while desalination is a water source for some of the Canarias Islands, located in the south Atlantic off the coast of western Africa. In parts of the Algarve region of Portugal, there are unsustainable water uses and varying seasonal and annual precipitation. This is combined with extensive coastal developments and roads, which varies the drainage and water retention patterns. In the future, climate change is predicted to result in higher summer temperatures and less and changing precipitation patterns. So many existing water shortages may increase.

Alterations in water quality due to pollution, nutrient flows, and the disposal of storm water and sewage and other urban wastes- particularly in estuaries, bays and shallow enclosed seas- maybe augmented by climate change and changing sea surface temperature, stratification, precipitation, and circulatory patterns. This is especially true for the Mediterranean and south Atlantic regions of Europe.

For example, much of the sewage and storm water from the larger settlements located on the Mediterranean Sea flows untreated or minimally treated into the sea. Additionally, nutrients and chemicals from agricultural production also enter rivers that enter the sea. For Adriatic Sea, this combination of inputs results in an eutrophic sea during parts of the year. Climate change, including increasing sea temperatures and stratification may increase the impact and extent of this eutrophication in the Adriatic and Mediterranean Seas, as well as other enclosed seas like the Baltic and Black Seas.

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Water uses and alterations in quality and quantity are also relevant for the Baltic Sea and largely tidal rivers like the Thames River and estuary. Significant cleanup isunderway in the Baltic, and measures are underway to combat the influx of nutrients and pollutants arising from the countries that share this shallow enclosed sea. The impacts of nutrient and pollutants will increase as the temperature warms. Due to antiquated storm water systems in London, routine flushing of combined storm waters and sewage occurs into the Thames River, with deleterious effects on water quality, fish populations, recreational uses, and tourism within that estuary. It can result in pollution that extends to the English Channel and the French coast.

Water quantity and quality is a key issue for coast and beach management throughout Europe. Many beaches can have unsafe levels of bacteria and can be unsafe for swimming, due to improper treatment of sewage and storm water, or after rainstorms due to releases of combined storm water and sewage. Considering sustainable tourist developments in the Mediterranean and south Atlantic region, it will be important to consider means to stabilize and minimize fresh water use for these developments, particularly if current uses and practices are unsustainable.

The overall design of sustainable tourist developments must consider local water sources, and the potential reduction of that water in the future due to climate change. This could affect the range and type of amenities offered (pools, golf courses, gardens) and the overall design of the facilities. For example, salt water could be used to supply pools, and certain types of wastewater could be segregated and re-used for watering gardens and cleaning.

Given the size of tourist developments, the disposition of wastewater and pollutants must also be considered to minimize adverse impacts on coastal and marine ecosystems. This could include proper sewage treatment facilities being constructed for larger tourist developments, even if they previously had not been as necessary for the local communities. An added concern specific to tourist developments may be controlling the use of fertilizers, nutrients and pesticides that are used to maintain gardens and hotel facilities. Otherwise, these substances could find their way into fresh and coastal waters, and increase pollution and eutrophication.

Drought, desertification and flooding

Climate change has resulted in increased forecasts of higher temperatures, as well as drought and desertification in the Mediterranean and south Atlantic regions. In the future, this may discourage tourism in the summer months, moving tourism more to other seasons or adjacent months. These and other regions of Europe are also vulnerable to changing seasonal and annual precipitation patterns, including more intense rainfall events and increased flooding at certain times of the year.

The projected temperature increases resulting from climate change for equatorial and tropical regions, and for Mediterranean and south Atlantic region are quite striking. These temperature impacts could be disproportionately felt in the summer

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tourist season, and could affect these tourist developments and destinations. Sustainable water uses will be relevant as temperatures increase, and have already been discussed.

Greater temperatures, as well as greater energy efficiencies and carbon reductions, will need to be considered for the design of future developments. Energy uses may have to increase in the future in order to provide cooling during the hotter summer period. Unless this energy is locally sourced or inexpensive, the economic viability of these developments could be affected. Sustainable tourist developments could be designed for energy efficiency and to generate and use renewable or low carbon energy sources.

Another more difficult factor to predict is the overall impact of temperature increases on the desire of tourists to travel to the Mediterranean region. Certain tourist developments may be less busy during the summer, and either become busier in the spring and fall, or lose overall visitors. These seasonal changes and potential decreases in overall visitors could impact the economic viability of small and large scale developments.

Changes in the seasonality of tourist demand could also affect working and social patterns in local communities, and eliminate or reduce the quieter period that allowed communities to tolerate large quantities of visitors during the remaining part of the year. Therefore, it would be useful to consider and plan for the possible social and cultural impacts of changing tourist demand on local communities.

Eutrophication

Eutrophication is the result of an anthropogenically induced alteration of the global nitrogen cycle, and just like climate change, should be regarded as a "global change". Eutrophication is usually treated scientifically and for management as a local and regional phenomenon. Coastal regions throughout the world and Europe are affected by eutrophication. More global approaches are now being considered in meetings such as the International Symposium on Research and Management of Eutrophication in Coastal Ecosystems from June 20 to 23, 2006 in Nyborg, Denmark.[12] This meeting included a keynote speaker, a working seminar, and produced some outcomes for the issue of climate change and eutrophication.

Within Europe, regional seas such as the Baltic and Mediterranean Seas are currently adversely affected by eutrophication, with climate change expected to intensify these adverse impacts. As well as monitoring fresh water impacts on coastal areas, it will be important to monitor impacts between seas such as the Mediterranean and Black Seas. For example, the Black Sea is strongly eutrophic, and enters the Mediterranean Sea at the North Aegean near the borders of Greece and Turkey .

[12] See http://eutro2006.dhi.dk/ for further information.

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Sea level rise, storm events and erosion

Coasts, deltas, estuaries, lagoons, enclosed seas, and arctic coasts are vulnerable coastal systems that are affected by sea level rise, storm events and erosion. All these types of coastal systems need to be considered when analyzing the impacts of climate change. Some European examples are the London and the Thames estuary, Venice and the Venice laguna, and the enclosed seas of the Adriatic, Mediterranean, Baltic and Black Seas. Representative examples of these vulnerable coastal ecosystems can be used as indicators of climate change, and to further understand approaches to and effectiveness of adaptation and mitigation strategies for climate change.

For the coasts, infrastructure and development, sea level rise will continue as an issue well into the future. It is interesting to note the shared and high vulnerability of lagunas, estuaries, deltas and arctic coasts to sea level rise, as well as storm surges and other extreme weather events. Given the extensive research as well as the high vulnerabilities within Europe, there are very relevant examples with in Europe. The vulnerability on northern Europe is discussed very fully in the Arctic Climate Impact Assessment Scientific Report. It is interesting to note the shared and high vulnerability of lagunas, estuaries, deltas and arctic coasts to sea level rise, as well as storm surges and other extreme weather events.

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London and the Thames Estuary are vulnerable to sea level rise, tidals surges, flooding in the upstream tributaries of the Thames Rivers, and heavy rainfalls. All these factors and potential negative impacts have been aggravated by increased building in the flood plain, antiquated sewage and storm water drainage systems, and increased built environment decreasing the absorption of rainfall. In its period of operation, the Thames Flood Barrier has been used to ameliorate the impacts of upstream flooding as well as tidal surges. An extensive study is now occurring under the Thames 2100 initiative to determine additional flood and tidal surge defence mechanisms that will be needed in the near future to address climatic augmented sea level rise and extreme weather events, where these costs can also be considered adaptive or preventative costs.

London and the Thames Estuary are currently protected to a high standard (generally 1:1000 years or 0.1% at the year 2030). The design of the Thames Barrier allowed for sea level rise but did not make any specific allowance for changes due to climate change in fluvial flows coming down the Thames or the size of storm surges arising in the North Sea. Rising sea level and rapidly increasing development within the tidal flood plain mean that flood risk is increasing and by the year 2030, improved arrangements will be required if flood protection standards are to be maintained at present levels.[13]

Two other examples are the Venice laguna and the central coastal region of Portugal. The Venice laguna, its infrastructure and its communities are very vulnerable to sea level rise and storm events, with natural and human-induced vulnerability augmented by climatic changes. Venice is not only threatened by high tides, but is sinking through subsidence, at the same time as the Adriatic Sea is rising. The surrounding marshes, which used to break the waves coming into the city, have gradually disappeared, and industrial development on the mainland has added to the increased subsidence and pollution.[14] Venice and the Venetian laguna, of which the city is one integral part, are vulnerable to both extreme weather events and "normal" flooding, which now occurs up to 10 times in one year. Due to the subsidence of the laguna (human induced and geological), as well as overall subsidence in the Adriatic Sea, Venice and the Venetian laguna are also vulnerable to even a 10 centimetre increase in sea level, and will be dramatically affected by a large increase in sea level.

The Moses project, which is comprised of 9 barriers, was approved in 2003, is now estimated to cost more than 5 billion euros, and is designed to rise from the seabed to block the inlets of the Venice laguna from the Adriatic Sea when high tides are forecast. . One measure of the actual adaptive or preventative costs may be required to protect Venice and the overall laguna is the 5.2 billion euro projected cost of the MOSES project, which is a dike structure designed to be used to prevent

[13] T Reeder et al, Broad Scale Tidal Flood Risk Assessment for London using MDSF and FLOODRANGER, paper for 3rd National CIWEM Conference, October 2004.
[14] O Ravera, The Lagoon of Venice: The result of both natural factors and human influence, J. Limmol 59(1) 10-30, 2000

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tidal surges from entering the laguna. Given the sensitivity of Venice and the overall laguna to climate change, it could also be considered as a model and indicator for global impacts of climate change for lagunas and coasts.

Coastal erosion is affected by extreme weather events, which can have major and catastrophic events on certain coasts. Some changes in sediment deposit may be amplified by climate change, such as loss of sediment in storm events.
In addition to extreme weather events, coasts may be erode due to changes in sediment deposit and removal due to the construction of offshore structures and alterations of rivers through dams and diversions, and resulting changes in water flows and sediment deposition. Much of the change in these sediment deposits is due to changes in water flows and damning on upstream rivers and watersheds, the removal of natural coastal habitats such as wetlands, the construction of coastal structures and defenses, and the construction of offshore structures.

The Atlantic coast in the central region of Portugal and settlements such as Aveiro and Figueira da Foz are very vulnerable to combination of climatic changes and coastal erosion, storm events, and changes in sediment deposit due to coastal dikes and groins and upstream dams. Due to its depth, and absence of replenishing sediment deposits, the Venice laguna can be impacted by shallow wave actions.

Sustainable tourism and climate change

As one of the world's largest and fastest growing economic activities, international tourism continues to grow and place stress on remaining natural habitats, which often underpin tourism. Sustainable tourist destinations have many responsibilities at they attempt to reduce negative tourism impact on their communities. Among other matters, efforts can be made to better provide the tourists and tour operators with information about destinations, and minimization of adverse impacts. The CoPraNet Partnership using existing achievements and ongoing international work within the network, including collaboration and the exchange of views to develop a transparent, international quality information scheme for tourism destinations. To the extent that it is an issue in these destinations, information needs to be included on climate change.

There is great reliance on tourism in Mediterranean and south Atlantic regions, and thus great vulnerability to climate change. Tourism in Northern European destinations, including the Baltic Sea, may benefit from climate shifts and general air and sea warming, but even these areas may still experience greater vulnerabilities due to changes in precipitation patterns, flooding, and eutrophication. An understanding of climatic impacts and mitigative and adaptive responses could also be incorporated into management of these destinations and regions.

The projected temperature increases due to climate change are quite striking for the Mediterranean region. These temperature impacts could be disproportionately felt in the prime tourist season in the summer, could affect existing tourist developments

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and destinations, and will need to be considered for the design of future developments.

Sustainable water uses have already been discussed. Energy uses may have to increase in the future in order to provide cooling during the hotter summer period. Unless this energy is locally sourced or inexpensive, the economic viability of these developments could be affected. Sustainable tourist developments could be designed for energy efficiency and to generate and use renewable or low carbon energy sources.

Another more difficult factor to predict is the overall impact of temperature increases on the desire of tourists to travel to the Mediterranean region. Certain tourist developments may be less busy during the summer, and either become busier in the spring and fall, or lose overall visitors. These seasonal changes and potential decreases in overall visitors could impact the economic viability of small and large scale developments.

Changes in the seasonality of tourist demand could also affect working and social patterns in local communities, and eliminate or reduce the quieter period that allowed communities to tolerate large quantities of visitors during the remaining part of the year. Therefore, it would be useful to consider and plan for the possible social and cultural impacts of changing tourist demand on local communities.

Coast and beach management approaches for climate change

Adaptive and mitigative measures for climate change need to be understandable and capable of implementation by local coastal and beach managers. This requires w plain language, clearly understood issues and indicators, and readily achievable measures. These measures may be illustrated by case studies in the beach management guide, or by the discussion of quality coast indicators by the CoPraNet partners.

Some recommended coast and beach management measures are:

- In complex ways, climate change can affect the ecological or carrying capacity of these natural ecosystems. In order to allow these coastal and marine ecosystems to adapt to the climate changes that will occur, overall human stresses, including those caused by tourist developments, must be reduced.

- Climate change requires an integrative and reiterative approach to planning that involves strategic environmental assessment and integrated management of these tourist developments, to determine the combined interaction of tourist developments and other human uses and climate change. This must be done before authorizing those uses and developments, and there needs to be subsequent monitoring of impacts.

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- Integrated coastal zone management must address tourist developments, human uses of coast and marine resources and climate change, in participatory ways that involve tourist businesses, local authorities and communities, non-governmental organizations (NGOs) and other stakeholders.

- Appropriate knowledge and monitoring technologies must be used at the appropriate scale. Local knowledge and information must be gathered locally, preferably by local parties, and combined with information from monitoring, satellite imagery and remote sensing at local, national and regional scales.

- While climate change is global, eutrophication will occur on a regional and local scale, particularly with bays, enclosed seas and lakes, and will require regional and local measures. Managing eutrophification requires reliable predictions, underpinned by consistent measurements and numerical modeling, but also informed local understandings of the changes and local responses.

- Appropriate mitigative and adaptive measures that can be considered and implemented by local governments, NGOs and peoples include measures for
    - overall water uses, and the uses and treatment of waste water,
    - minimizing energy and carbon emissions,
    - appropriate erosion and soft and hard coastal and beach defense measures, including setbacks for built environment, and
    - retention of coastal and marine ecosystems such as beaches, estuaries, and wetlands in a natural states as a defensive measure and to enhance biodiversity.

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