

# Climate Change, Heritage and Tourism:

## *Implications for Ireland's Coast and Inland Waterways*

Heritage Council and Fáilte Ireland

Editors: Kelly, B., and Stack, M.

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## EXECUTIVE SUMMARY

The fourth (and latest) report from the Intergovernmental Panel on Climate Change (IPCC) in 2007 states that warming of the climate system is now unequivocal and that human activities are very likely to be the cause of recent warming. However, it is not only the challenges of rising temperatures that face us, but also related changes such as extreme weather events, changes to current rainfall patterns leading to increased flooding and more prolonged droughts, as well as rising sea levels due to melting ice caps and glaciers and thermal expansion of the oceans.

In the context of ever-growing concern in relation to climate change, the Heritage Council and Fáilte Ireland commissioned a review on the research carried out elsewhere to date in relation to the potential impacts of climate change on Ireland's maritime and inland waterways heritage, with a particular focus on those resources upon which tourism is dependent. The focus on these two elements of heritage is because of their particular vulnerability to climate change.

The purpose of this report is to inform Heritage Council and Fáilte Ireland recommendations to Government for priorities for action or further research in this area, and also to inform Heritage Council and Fáilte Ireland plans and strategies in the future.

Climate change presents a significant and imminent threat to the heritage of our coasts and inland waterways, to the ways of life which co-exist with these environments, and to our well being. The principal manifestations of climate change in Ireland are anticipated to be:

- Increased mean annual temperatures
- Increased mean annual rainfall, but with the likelihood of drier summers
- More extreme weather including heavy downpours and more intense storms
- Higher sea levels due to melting ice and thermal expansion

The direct impacts of these climate change phenomena will include:

- Higher evaporation and regular summer drought conditions, albeit possibly interspersed with heavy downpours
- Alluvial flooding and occasional flash floods
- Greater coastal erosion
- Coastal flooding and the gradual inundation of low lying areas, especially following tidal surges exacerbated by the combined effect of sea level rise and storms

These impacts present serious consequences for heritage and for socio-economic activity that is directly or indirectly associated with it, including tourism and amenity. This report sets out to determine what exactly existing research is telling us these consequences might be.

In relation to natural heritage, one of the main findings of the review was that there was a general lack of published information in this area, identifying a significant deficiency in Ireland's preparedness for climate change. Many plant, insect, bird and animal species, and the habitats upon which these depend are highly sensitive to changes in temperature and water availability. Impoverished biodiversity itself is regrettable and costly, and will also result in poorer productivity to sectors such as agriculture and fisheries and a loss of the ecological goods and services of which we are among the beneficiaries (Bullock *et al.*, 2008). Also, species loss will create niche openings, into which other species can move, a situation that has been identified as an important prerequisite for biological invasion.

Future changes in climate are likely to have significant impacts on water resources in Ireland, which may alter their carrying capacity for many species. More intense rainfall patterns are expected to result in increased runoff. This will carry increased sediment and nutrient loads into waterways. More regular flood events will put increasing pressure on sewage treatment plants in systems that integrate rainwater runoff. These are designed to discharge everything over their storage capacity directly into waterways untreated with deleterious effects for the ecosystems (Gray, 2004). The repercussions of a reduced water quality will have a profound impact on the drinking water supply in certain areas. It will also render some of the waterbodies unsuitable for certain recreational purposes including angling. The adverse effect of climate change on water quality will be exacerbated by increasing resource and abstraction demands during low flow periods.

Ireland is already experiencing large scale habitat loss, especially along the coastline (McElwain & Sweeney, 2006). Habitat loss is of particular concern in coastal areas where the combined effect of sea level rise and increasing storm surges is likely to cause large scale erosion of coastal habitats and saline inundation landwards (IPCC, 2007). Wetlands and estuaries, two of the most productive ecosystems may shrink significantly as a result of climate change.

There is a need for good quality information on the biological effects of climate change to inform adaptive measures. This information needs to be available to all stakeholders. Two of the most important adaptive measures will be the creation of alternative space for nature and relieving the stresses on the aquatic environment from man-made pressures such as nutrient enrichment, arterial drainage of wetlands or pollution. A permeable landscape would provide species with the maximum chance for adaptability and refuge while the EU Water Framework Directive will provide the instruments by which pressures on our water environment are alleviated.

A review of the potential impact of climate change on Ireland's built and archaeological heritage along our coasts and inland waterways also identified a general consensus that little work has been done anywhere on the potential impacts of climate change on cultural heritage, particularly scientific research. In Ireland there is also a lack of information/data collection in relation to determining and mapping the actual extent of our cultural heritage (particularly archaeological assets) along our coasts and inshore waters. Increasing fluctuations in temperature and moisture are likely to result in accelerated decay of materials which make up the building fabric of our cultural heritage, resulting in an increasing demand for building maintenance. An increase in flood events could undermine our stock of inland waterways heritage, through higher river velocities. Bridges can be at risk from build up of flotsam as well as the water pressure. Extreme rainfall events, and prolonged drought will threaten the canal banks crossing the mid-land bogs. A rise in sea level and increased storminess will exacerbate coastal erosion, threatening the survival of many coastal monuments and buildings, wrecks, and coastal archaeological sites particularly those in the intertidal zone. Both natural and cultural heritage are also at risk from inappropriate measures planned to alleviate flooding and sea level rise. Poorly planned hard defences are likely to cause additional problems of erosion along Ireland's coasts. Intrusive flood relief schemes in historic town centres will compromise the character of these townscapes as well as removing distinctive features.

Further research to identify the extent, significance, and vulnerability of our cultural heritage in the coastal area is required in order to plan for its management in the light of these climate change impacts. Regular maintenance of built structures is also needed to assist them in withstanding extreme weather events. The public must also be made aware of the processes of natural decay, and the role of potential climate change impacts in exacerbating these. We also need to set up a framework for setting priorities on what elements of cultural heritage to save or not, as advocated by the International Council for Monuments and Sites (ICOMOS) and the United Nations Educational, Scientific and Cultural Organisation (UNESCO).

The tourism sector depends heavily on a natural and cultural heritage that underpins a wide range of tourist and amenity activities. The quality of sightseeing in Ireland, coupled with our reputation for a clean and unspoilt environment have always been major draws for international visitors. Climate change will lead to some significant changes in tourism flows over time. Locations at particular risk in Europe include the Mediterranean and Alpine ski resorts. Impacts in Ireland will be moderated by our temperate climate. Undoubtedly, some of these impacts will be positive from a tourism point of view. Warmer, drier summer weather will increase the appeal of many Irish coastal resorts and of water-based and other outdoor activities. Relative to Mediterranean regions, Ireland as a tourism destination may benefit from increased visitor numbers due to climate change. However, there may be adverse impacts associated with this and it will be necessary to prepare for these. Example of these include an increased potential for eutrophication of surface waters or the possible inundation of popular beaches and seaside resorts, or an increase in invasive species at the expense of native species. Careful management of climate related impacts such as water pollution will be essential in order to safeguard positive destination image in the long term.

In addition, substantially increased visitor numbers may also put additional pressure on the already vulnerable natural and cultural heritage assets upon which the tourism industry relies. Therefore it is essential that sustainable tourism development and management policies are employed which take into consideration the potential impact these policies may have on our natural and cultural heritage assets.

Climate change presents serious challenges in terms of protecting our heritage and associated tourism and amenity value. If warming trends are in line with current IPCC predictions, we are likely to have the opportunity to put in place adaptive strategies. If impacts are greater than anticipated, more extreme strategies will be required to balance heritage conservation with other economic and social needs. In all cases, a co-ordinated approach between government departments and agencies, along with local authori-

ties, NGOs, and community groups will be required; this is of particular relevance to managing the coastal zone. The recommendations arising from this report represent a first step, but decisive political leadership and integrated policy-making are needed to ensure that they are acted on, and that further research and actions are undertaken in this area.

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## ACHOIMRE FHEIDHMEACH

Sonraíonn an ceathrú tuarascáil (an ceann is déanaí) ó Phainéal Idir-Rialtasach ar an Athrú Aeráide (PIAA) in 2007 go bhfuil téamh an chóras aeráide thar a bheith cinnte anois agus go bhfuil an-dóchúlacht ann gur gníomhaíochtaí an duine is cúis leis an téamh is déanaí. Ar a shon sin, ní hiad na dúshláin maidir le teochtaí a bheith ag ardú an t-aon dúshlán amháin atá romhainn. Tá athruithe gaolmhara ann chomh maith, tosa foircneacha aimsire, athruithe ar na patrúin reatha báistí óna n-eascraíonn tuilte méadaithe agus triomach a mhaireann níos sia, chomh maith le leibhéal na farraige a bheith ag ardú de dheasca na n-oighearchaidhpeanna agus na n-oighearshruthanna a bheith ag leá agus forleathadh teirmeach na n-aigéan.

I gcomhthéacs na cúise imní atá ag síormhéadú maidir le hathrú aeráide, rinne an Chomhairle Oidhreachta agus Fáilte Éireann coimisiún ar athbhreithniú ar an taighde a déanadh in áiteanna eile maidir le tionchair ionchasacha ag athrú aeráide ar oidhreacht uiscebhealaí muirí agus intíre na hÉireann, le fócas ar leith ar na hacmhainní sin ar a mbíonn an turasóireacht ag brath. Díritear ar an dá eilimint oidhreachta seo mar gheall ar a leochaileacht maidir le hathrú aeráide.

Is cuspóir den tuarascáil seo é eolasú a dhéanamh ar mholtaí na Comhairle Oidhreachta agus Fáilte Ireland don Rialtas le go ndéanfaí tús áite a thabhairt do gníomhaíochtaí nó taighde breise a dhéanamh sa réimse seo, agus chomh maith chun pleananna agus straitéisí na Comhairle Oidhreachta agus Fáilte Éireann a eolasú sa todhchaí.

Tá garbhagairt shuntasach san athrú aeráide ar ár gcóstaí agus ar ár n-uiscebhealaí intíre, ar na modhanna beatha a chomh mhaireann laistigh de na comhshaoil seo agus ar ár leas féin. Faoi na 2080oidí, i.e. an chéad céad bliain eile, meastar gurb iad seo a leanas a bheidh ina bpríomhléirithe an athraithe aeráide in Éirinn:

- Méadú sna meánteochtaí bliantúla;
- Méadú sa meánmhéid bliantúil báistí, ach an dóchúlacht go mbeidh samhraidh níos trioma ann;
- Aimsir níos measa ag áireamh duartain throma agus stoirmeacha níos déine; agus
- Leibhéal níos airde farraige de dheasca oighear a bheith ag leá agus forleathadh teirmeachta.

I measc na dtionchar díreacha a bheidh acu seo ar an bhfeiniméan athraithe aeráide beidh:

- Galú níos airde agus triomaigh rialta samhraidh, cé gur féidir go mbeadh duartain throma ann lena linn;
- Tuilte gláracha agus maidhm thuile ó am go chéile;
- Creimeadh níos mó cósta; agus
- Tuilte cósta agus sceitheadh de réir a chéile na gceantar ísle go háirithe tar éis do bhorradh taoide méadaithe ag ardú ar leibhéal na farraige agus ag stoirmeacha.

Tá iarmhairtí tromchúiseacha ag baint leis na tionchair seo maidir leis an oidhreacht agus le gníomhaíochtaí socheacnamaíocha a ghabhann léi go díreach nó go hindíreach, turasóireacht agus taitneamhacht san áireamh. Is cuspóir don tuarascáil seo é cinneadh a dhéanamh maidir le cad é go díreach a insíonn taighde atá déanta cheana féin dúinn maidir leis na hiarmhairtí a fhéadfadh a bheith i gceist.

Maidir le hoidhreacht nádúrtha, ceann de phríomhthorthaí an athbhreithnithe ab ea an easpa ginearálta eolais fhoilsithe sa réimse seo, agus aon easpa suntasach in ullmhacht na hÉireann d'athrú aeráide a aithint. Tá mórán speiceas plandaí, feithide, éan agus ainmhí, agus na gnáthóga ar a mbraitheann an-íogair maidir le hathruithe teochta agus fáil ar uisce. Tá bithéagsúlacht dhealbh ina chúis áiféala agus tá a leithéid costasach, agus dá dheasca, beidh táirgiúlacht níos boichte in earnálacha mar thalmhaíocht agus iascaireacht chomh maith le cailteanas earraí agus seirbhísí éiceolaíochta go bhfuilimid i measc a dtairbhíthe (Bullock et al., 2008). Chomh maith leis sin, cruthóidh cailteanas speiceas oscailtí nideoige, gur féidir le speicis eile dul isteach iontu, cúinse a aithnítear a bheith ina réamhriachtanas tábhachtach d'ionradh bithéolaíochta.

Is mó is dócha go mbeidh tionchair shuntasacha ag athruithe aeráide an todhchaí ar acmhainní uisce in Éirinn, rud a fhéadfadh a n-acmhainn cothabhála do mhórán speiceas a athrú. Meastar go méadóidh an rith chun srutha de dheasca patrúin níos déine báistí. Méadóidh seo na hualaí dríodair agus cothaithigh isteach sna huiscebhealaí. Cuirfidh teagmhais níos rialta tuile brú méadaithe ar fhearaí chóireála séarachais i gcórais a chomhtháthaíonn rith chun srutha báistí. Deartar iad sin leis an uile ní os cionn a n-acmhainn stórála a sceitheadh go díreach go dtí uiscebhealaí gan chóireáil a bheith déanta orthu agus bíonn éifeachtaí dochracha acu ar na héiceachórais (Gray, 2004). Beidh mórthionchar ag na hiarmhairtí a ghabhann le caighdeán laghdaithe uisce ar an soláthar uisce óil i gceantair áirithe. Dá dhroim chomh maith beidh cuid de na dobharlaigh neamhoiriúnach do chuspóirí áirithe caitheamh aimsire ar a n-áirítear slatiascaireacht. Déanfar éifeacht dhíobhálach an athraithe aeráide ar chaighdeán an uisce níos measa trí mhéadú ar na héilimh acmhainne agus astarraingthe le linn tréimhsí ísealsreibe.

Tá cailteanas gnáthóg ar scála mór ar bun in Éirinn cheana féin, go háirithe ar feadh an chósta (McElwain & Sweeney, 2006). Is cúis ar leith inní é cailteanas gnáthóg i gceantair an chósta nuair is mó is dócha go gcuirfidh ardú leibhéal na farraige agus borradh méadaithe stoirme le creimeadh, ar scála mór, na ngnáthóg chósta agus an sceitheadh salanda i dtreo na talún (PIAA, 2007). Is féidir go laghdódh dhá cheann de na héiceachórais is táirgiúla go suntasach de dhroim athraithe aeráide, is iad sin bogaigh agus inbhir.

Tá gá le heolas ardchaighdeán maidir leis na héifeachtaí bithéolaíochta um athrú aeráide chun eolasú a dhéanamh ar bheartas oiriúnaitheachta. Caithfidh an t-eolas seo a bheith ar fáil don uile pháirtí leasmhar. Is iad an dá bheartas tábhachtach oiriúnaitheachta a bheidh ann ná spás malartach a chruthú don nádúr agus an strus ar an gcomhshaol uisceach a laghdú ó bhrúnna de dhéantús an duine mar shabhairí cothaitheach, draenáil artaireach na mbogach nó truailliú. Sholáthródh tírdhreach tréscailteach an deis is mó do speiceas d'inoiriúnaitheacht agus do thearmann agus soláthródh Creat-treoir Uisce an AE na hionstraimí trína ndéanfar brúnna ar ár gcomhshaol uisce a laghdú.

D'aithin athbhreithniú ar thionchar féideartha an athraithe aeráide ar oidhreacht thógtha agus seandálaíochta na hÉireann ar feadh ár gcóstaí agus uiscebhealaí intíre comhdhearcaidh na coitiantachta nach bhfuil an oiread sin oibre déanta in aon áit maidir leis na tionchair fhéideartha ag athrú aeráide ar an oidhreacht chultúrtha, go háirithe taighde eolaíochta. In Éirinn tá easpa ann chomh maith maidir le heolas/sonraí a bhailiú maidir le cinneadh agus mapáil a dhéanamh ar fhíormhéid ár n-oidhreachtachtaí cultúrtha (go háirithe sócmhainní seandálaíochta) ar feadh ár gcóstaí agus ár n-uisce cladaigh. Is mó is dócha go mbeidh meath brostaithe ar ábhair chreatlach foirgnimh ár n-oidhreacht chultúrtha de dheasca iomlaidí i dteocht agus i dtaise agus dá réir beidh éileamh níos mó ar chothabháil thógála. D'fhéadfadh méadú i dteagmhais tuile dochar a dhéanamh dár stoc d'oidhreacht uiscebhealaí intíre, trí luasanna níos airde abhann. Is féidir do dhroichid a bheith i mbaol ó thiomargadh raice chomh maith le brú an uisce. Cuirfidh tulcaí foircneacha báistí, agus triomach faidreiseach brucha na gcanálacha a thrasnaíonn na portaigh lár tíre i mbaol. Déanfaidh ardú i leibhéal na farraige, agus méadú i stoirmeacha creimeadh cósta a dhianú, ag cur mórán séadchomhartha agus foirgneamh cósta, báid bháite agus láithreáin seandálaíochta cósta i mbaol go háirithe iad seo atá sa chrios idirthaoideach. Tá an oidhreacht nádúrtha agus chultúrtha araon i mbaol chomh maith ó bheartais mhíchúil um laghdú a dhéanamh ar thuilte agus ar leibhéal na farraige a bheith ag ardú. Is mó is dócha go gcruthóidh cosaintí crua drochphleanáilte fadhbanna breise maidir le creimeadh ar feadh cóstaí na hÉireann. Déanfaidh scéimeanna ionsáiteacha faoisimh tuilte i gcroílár bhailte stairiúla dochar do shaintréith na ndreacha baile seo chomh maith le sainghnéithe a bhaint as.

Tá gá de thaighde breise le go n-aithneofaí méid, tábhacht agus leochaileacht ár n-oidhreachtachtaí cultúrtha sa cheantar cósta d'fhonn pleanáil a dhéanamh dá bainistiú i bhfianaise na dtionchar ag an athrú aeráide seo. Tá gá de chothabháil rialta na struchtúr tógtha chomh maith le cúnamh a thabhairt dóibh le tosca foircneacha aimsire a sheasamh. Caithfidh an pobal a bheith ar an eolas maidir leis na próisis um mheath nádúrtha, agus an ról ag tionchair fhéideartha an athrú aeráide maidir le dianú na bpróiseas seo. Caithfidh creatlach a bhunú chomh maith le go socrófaí tosaíochtaí ar cad iad na heilimintí den oidhreacht nádúrtha is gá nó nach gá a shábháil, mar a áitíonn an Chomhairle Idirnáisiúnta um Shéadchomharthaí agus Shuíomhanna (CISS) agus Eagraíocht Oideachais, Eolaíochta agus Chultúir na Náisiún Aontaithe (EOECNA).

Tá earnáil na turasóireachta ag brath go mór ar oidhreacht nádúrtha agus chultúrtha a chuireann taca le raon fairsing gníomhaíochtaí turasóireachta agus taitneamhachta. Tá caighdeán na fámaireachta in Éirinn, chomh maith lenár gclú mar thimpeallacht ghlan agus neamh-mhillte ina chúis meallta i gcónaí do chuairteoirí idirnáisiúnta. Cuirfidh athrú aeráide tús le roinnt athruithe sun-tasacha i sreabhadh na turasóireachta le himeacht aimsire. I measc na n-áiteanna san Eoraip a bheidh go mór i mbaol beidh an Mheánmhuir agus ionaid sciála na nAlp. Déanfaidh ár n-aeráid mheasartha na tionchair ar Éirinn a mhaolú. Gan amhras, beidh roinnt de na tionchair seo dearfach ó thaobh na turasóireachta de. Méadóidh aimsir shamhraidh níos teo, níos trioma an tarraingt go mórán ionad cósta in Éirinn agus go gníomhaíochtaí uiscebhunaithe agus gníomhaíochtaí faoin aer. I gcomparáid le réigiúin na Meánmhara, is féidir go mbainfidh Éire, ina ceann scríbe turasóireachta, leas as an méadú ar líon na gcuaireoirí de thoradh an athrú aeráide. Ar a shon sin, is féidir go mbeadh drochthionchair ag gabháil leis seo agus caithfear a bheith ullamh le haghaidh a thabhairt orthu seo. I measc na ndrochthionchar seo tá acmhainn mhéadaithe d'eotrófú na n-uiscí dromchla nó sceitheadh féideartha go móthránna agus go hionaid cois farraige, nó méadú i speiceas ionracha chun díobhála do speicis dhúchasacha. Beidh bainistiú cáiréiseach na dtionchar gaolmhara aeráide mar thruailliú uisce rithabhachtach d'fhonn íomhá dearfach mar cheann scríbe a chosaint go fadtéarmach.

Ina theannta sin, is féidir go gcuirfeadh líon méadaithe na gcuaireoirí brú breise ar shócmhainní leochaileacha oidhreachta nádúrtha agus cultúrtha go bhfuil tionscal na turasóireachta ag brath orthu. Dá bhrí sin tá sé thar a bheith tábhachtach go nglacfaí le polasaithe inbhuanaithe forbartha agus bainistíochta turasóireachta a chuireann san áireamh tionchar féideartha na bpolasaithe seo ar ár sócmhainní oidhreachta nádúrtha agus cultúrtha.

Cuireann athrú aeráide dúshláin thromchúiseacha os ár gcomhair maidir lenár n-oidhreacht agus an luach turasóireachta agus taitneamhachta a ghabhann léi a chosaint. Má bhíonn treochtaí téimh ag teacht le réamh-mheastacháin reatha an PIAA, tá an dóchúlacht ann go mbeidh an deis againn straitéisí oiriúnaitheachta a chur i bhfeidhm. Má bhíonn na tionchair níos mó ná mar a meastar, beidh gá le straitéisí níos déine le caomhnú na hoidhreachta a chothromú le riachtanais eile eacnamaíochta agus sóisialta. I ngach cás, beidh gá le cur chuige comhordaithe idir ranna agus gníomhaireachtaí rialtais, chomh maith le húdaráis áitiúla, beidh gá d'eagraíochtaí neamhrialtasacha agus do ghrúpaí pobail; tá ábharthacht ar leith ag baint leis seo maidir leis an gcrios cósta a bhainistiú. Is ionann na moltaí a eascrann ón tuarascáil seo agus an chéad chéim, ach tá gá de chinnireacht chinntitheach polaitiúil agus déanamh polasaí comhtháite le deimhin a dhéanamh go gcuirtear i bhfeidhm agus go rachfar i mbun taighde agus gníomhaíochtaí breise sa réimse seo.

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## FOREWORD

Climate change presents a significant and imminent threat to our natural and built environments, to the ways of life which co-exist with these environments, and to our general wellbeing. In 2007, due to the growing concern over this issue, the Heritage Council and Fáilte Ireland jointly commissioned a review of the existing research on the potential impacts of climate change on Ireland's coastal and inland waterways heritage, with a particular focus on the resources upon which tourism depends. The purpose of the review was to inform the two agencies of potential changes and to provide the foundation of future recommendations to Government on the priorities for action.

The report builds on existing research and knowledge available to the end of 2008. Gaps in current knowledge were identified and, where further research is required, subsequent recommendations have been made. The key recommendations arising from this review have been outlined under a number of themes in the final chapter of this report. These recommendations centre on the integration of heritage and tourism policies, adaptation, research, awareness, training, and resource management.

There is an inextricable link between tourism in Ireland and our natural and cultural heritage assets. The tourism sector depends heavily on these assets as they underpin a wide range of tourist and amenity activities. Therefore it is essential that all tourism and heritage policies are built upon the principles of sustainability. Both the Heritage Council and Fáilte Ireland have a significant role to play in ensuring this is the case. However both organisations also have separate statutory functions, and in some instances, separate policies and plans will be required to respond to the various issues and stakeholders involved. Therefore, it is envisaged that the recommendations in this report will also be used to inform future separate Heritage Council and Fáilte Ireland plans and strategies.

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The authors:

Rowan Fealy and Conor Murphy, (ICARUS)  
Marcin Penk, John Brophy, and Roisin Nash (Ecoserve)  
Beatrice Kelly (Heritage Council)  
Craig Bullock (Optimize)  
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## GLOSSARY OF TERMS

Abiotic	Non-living, referring to physical and chemical rather than biological factors.
Adaptation	Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.
Algae	Photosynthetic, often microscopic and planktonic, organisms occurring in marine and freshwater ecosystems.
Algal bloom	A reproductive explosion of algae in a lake, river or ocean.
Anadromous	Breed in freshwater and migrate to seawater.
Anthropogenic	Resulting from or produced by human beings.
Annex I	The group of countries included in Annex I (as amended in 1998) to the UNFCCC, including all the OECD countries and economies in transition. Under Articles 4.2 (a) and 4.2 (b) of the Convention, Annex I countries committed themselves specifically to the aim of returning individually or jointly to their 1990 levels of greenhouse gas emissions by the year 2000. By default, the other countries are referred to as non Annex I countries.
Annex II	The group of countries included in Annex II to the UNFCCC, including all OECD countries. Under Article 4.2 (g) of the Convention, these countries are expected to provide financial resources to assist developing countries to comply with their obligations, such as preparing national reports. Annex II countries are also expected to promote the transfer of environmentally sound technologies to developing countries.
Aquaculture	The managed cultivation of aquatic plants or animals such as salmon or shellfish held in captivity for the purpose of harvesting.
Aquifer	A stratum of permeable rock that bears water.
Atmosphere	The gaseous envelope surrounding the Earth.
Basin	The drainage area of a lake, river or stream.
Benthic	Sea or river bed.
Biodiversity	The total diversity of all organisms and ecosystems at various spatial scales.
Biofuel	A fuel produced from organic matter or combustible oils produced by plants.
Biogeography	Distribution of biodiversity over space and time.
Biosphere	The part of the earth comprising all ecosystems and living organisms in the atmosphere, on land or in the oceans, including derived dead or organic matter, such as litter, soil organic matter, and oceanic detritus.
Biotic	Living, referring to biological factors.
Biotoxin	Toxins produced by marine plankton.
Catadramous	Breeding in seawater and migrating to freshwater.
Clean development mechanisms	CDM allows Annex I countries to fund emission reduction projects in Annex II countries to offset their own emissions. This allows non Annex I countries to benefit from activities re-

sulting in certified emissions reductions (CER).

Climate	This can usually be defined (in a narrow sense) as the 'average weather'.
Climate change	Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity.
Coastal squeeze	The squeeze of coastal ecosystems (e.g. salt marshes, mangroves, mud, and sand flats) between the rising sea levels and naturally or artificially fixed shorelines, including hard engineering defences.
Downscaling	A method that derives local- to regional-scale (10 to 100km) information from larger-scale models or data analyses.
Ecosystem	An interactive system formed from all living organisms and their abiotic (physical and chemical) environment within a given area.
Ecological axis	Any environmental (living or non living) factor relating to living conditions
Ecological community	A community of plants and animals characterised by a typical assemblage of species and their abundances.
Ecological niche	A set of all possible ecological axis, inhabitable space of a given species
Emission reduction unit	Equal to one metric tonne of CO <sub>2</sub> -equivalent emissions reduced or sequestered arising from a Joint Implementation Project.
Emissions trading	A market based approach to achieving environmental objectives. It allows those reducing GHG emissions below their emission cap to use or trade the excess.
Endemic	Restricted or peculiar to a locality or region.
Erosion	The process of removal and transport of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, winds and underground waters.
Eutrophication	An increase in chemical nutrients (compounds containing nitrogen or phosphorous) in an ecosystem, and may occur on land or in water. However, the term is often used to mean the resultant increase in the ecosystem's primary productivity (excessive plant growth and decay), and further effects including lack of oxygen and severe reductions in water quality, fish, and other animal populations.
Flexible mechanisms	The Kyoto Protocol includes three so-called 'flexible mechanisms', instruments which allow governments in industrialised countries to achieve parts of their emission reduction commitments under the Kyoto Protocol through projects abroad rather than through action or policy changes at home. These include Joint Implementation, Emissions Trading, and Clean Development Mechanisms.
Flotsam	Debris in water.
Food web	The network of trophic relationships within an ecological community involving several interconnected food chains.
Global warming potential	An index, based upon radiative properties of well mixed greenhouse gases, measuring the radiative forcing of a unit mass of a well mixed greenhouse gas in the present-day atmosphere integrated over a chosen time horizon, relative to that of carbon dioxide.
Greenhouse gases	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and an-

thropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the earth's surface, the atmosphere, and clouds. Water vapour (H<sub>2</sub>O), carbon dioxide (CO<sub>2</sub>), nitrous oxide (N<sub>2</sub>O), methane (CH<sub>4</sub>) and ozone (O<sub>3</sub>) are the primary greenhouse gases in the Earth's atmosphere. As well as CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub>, the Kyoto Protocol also deals with the greenhouse gases sulphur hexafluoride (SF<sub>6</sub>), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

Gross domestic product	The monetary value of all goods and services produced within a nation.
Habitat	The locality or natural home in which a particular plant, animal, or group of closely associated organisms lives.
Intertidal/ littoral	The area, or organisms that are exposed to the air at low tide and submerged at high tide
Isostatic rebound	Post-glacial uplift in the land relative to sea
Invasive species	Species which spread, outcompete and outnumber existing species leading to system disturbance.
Joint implementation	JI is a market based implementation mechanism defined in Article 6 of the Kyoto Protocol, allowing Annex I countries or companies from these countries to implement projects jointly that limit or reduce emissions or enhance sinks, and to share the emission reduction units (ERU).
Lithology	The study of rocks with particular emphasis on their description and classification.
Macroinvertebrates	Invertebrate fauna greater than 0.5mm.
Macrophytes	Macroscopic (visible with an unequipped eye) forms of aquatic vegetation including plants and algae.
Managed retreat	In the context of coastal erosion, managed retreat (also managed realignment) allows an area that was not previously exposed to flooding by the sea to become flooded by removing coastal protection.
Meridional overturning circulation	Meridional (north-south) overturning circulation in the ocean quantified by zonal (east-west) sums of mass transports in depth or density layers.
Methane clathrates	Methane clathrate, also called methane hydrate or methane ice, is a solid form of water that contains a large amount of methane within its crystal structure (a clathrate hydrate).
Mitigation	An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks.
Morphology	The form and structure of an organism or land-form, or any of its parts.
North Atlantic oscillation	Consists of opposing variations in barometric pressure near Iceland and near the Azores. It therefore corresponds to fluctuations in the strength of the main westerly winds across the Atlantic into Europe, and thus to fluctuations in the embedded cyclones with their associated frontal systems.
Osmotic pressure	Osmotic pressure is the hydrostatic pressure produced by a difference in concentration between solutions on the two sides of a surface such as a semi permeable membrane.
Permafrost	Ground that remains at or below 0°C for at least two consecutive years.



Phenology	The study of natural phenomena that recur periodically (e.g. development stages, migration) and their relation to climate and seasonal changes.
Plankton	Microscopic aquatic organisms that drift or swim weakly.
Positive feedback	Natural mechanisms that (in climate terms) could accelerate predicted rates of climate change.
Pre-industrial and industrial	Normally refers to the periods before and after 1750 respectively.
Radiative forcing	The change in net vertical irradiance at the tropopause due to an internal or external change in the forcing of the climate system, such as a change in the concentration of CO <sub>2</sub> or the output of the sun.
Run-off	The part of precipitation that does not evaporate and is not transpired.
Species	A group of organisms capable of interbreeding and producing fertile offspring.
Streamflow	Water flow within a river channel (m <sup>3</sup> /s).
Sublittoral	The area, or organisms, that are permanently covered with water (below intertidal).
Suspended solids	Organic and inorganic material in the water flow that is not dissolved.
Sustainable development	Development that meets the cultural, social, political and economic needs of the present generation without comprising the ability of future generations to meet their own needs.
Thermal expansion	In connection with sea level, this refers to the increase in volume (and decrease in density) that results from warming water. A warming of the ocean leads to an expansion of the ocean volume and hence an increase in sea level.
Thermohaline (circulation)	Large-scale circulation in the ocean that transforms low-density upper ocean waters to higher density intermediate and deep waters and returns those waters back to the upper ocean.
Trophic level (or status)	The position that an organism occupies within a food chain.

## LIST OF ABBREVIATIONS

AOGCMs	Atmosphere-Ocean Global Climate Model
BIM	Bord Iasca Mhara
C4I	Community Climate Change Consortium for Ireland
CBA	Council for British Archaeology
CDM	Clean Development Mechanisms
CPI	Climate Prediction Index
DEHLG	Department of Environment, Heritage and Local Government
ENSO	El Niño-Southern Oscillation
ECN	Environmental Change Network ( UK)
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
EU	European Union
FP7	Seventh Research Framework Programme
GCMs	Global Climate Models
GHGs	Greenhouse Gases
ICARUS	Irish Climate Analysis and Research Unit
ICOMOS	International Council for Monuments and Sites
ICZM	Integrated Coastal Zone Management
IPCC	International Panel on Climate Change
ISAF	Irish Sea Angling Federation
IWAC	Inland Waterways Advisory Council (UK)
IWAI	Inland Waterway Association of Ireland
InterEST	Intertidal Ecology Skills Training
MDV	multi-decadal variability
MCC	Marine Climate Change
MCCIP	Marine Climate Change Impacts Partnership (UK)
NAD	North Atlantic Drift
NAO	North Atlantic Oscillation
NHA	Natural Heritage Area
NI	Northern Ireland
NPWS	National Parks and Wildlife Service
NT	National Trust
NUI	National University of Ireland
OECD	Organisation for Economic Co-operation and Development
OPW	Office of Public Works
PIANC	Permanent International Association of Navigational Congresses
RBD	River Basin District
RCZAS	Rapid Coastal Zone Assessment Surveys
RSL	Relative Sea Level

SAHFOS	Sir Alister Hardy Foundation for Ocean Science
SAC	Special Area of Conservation
SCAPE	Scottish Archaeology and the Problem of Erosion
SEA	Strategic Environmental Assessment
SLR	Sea Level Rise
SMP	Shoreline Management Plan
SPA	Special Protection Area
SRES	Special Report on Emissions Scenarios
TCD	Trinity College Dublin
UK	United Kingdom
UCD	University College Dublin
UNEP	United Nations Environment Programme
UNESCO	United Nations Education, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
UNWTO	United Nations World Tourism Organisation
WI	Waterways Ireland
WMO	World Meteorological Organisation

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## Part 1: Introduction and policy overview

### Chapter 1. INTRODUCTION

Author: Mary Stack (Fáilte Ireland)

#### 1.1 Introduction

In 2007 the Heritage Council and Fáilte Ireland commissioned a review of the research carried out to date on the potential impacts of climate change on Ireland's maritime and inland waterways heritage, with a particular focus on those resources upon which tourism depends. The purpose of this review is to inform Heritage Council and Fáilte Ireland recommendations to Government, to identify priorities for action or further research in this area, and to inform the future plans and strategies of the Heritage Council and Fáilte Ireland.

The role of the Heritage Council is to propose policies and priorities for the identification, protection, preservation and enhancement of Ireland's built, cultural, and natural heritage. The Council also has a particular responsibility to promote interest, education, knowledge, and pride in the national heritage.

Fáilte Ireland, the National Tourism Development Authority, works in strategic partnership with tourism interests (such as our natural and cultural heritage) to support the industry in its efforts to be more competitive and more profitable, and to help individual enterprises to enhance their performance. Fáilte Ireland's role is to guide and develop a sustainable tourism sector in Ireland.

There is an inextricable link between tourism in Ireland and our natural and cultural heritage assets. The tourism sector depends heavily on these assets, which underpin a wide range of tourist and amenity activities. Therefore it is essential that all tourism policies are built upon the principles of sustainability, and do not compromise the asset upon which tourism is based, namely the environment. Climate change policy has gained significant momentum globally and at EU level over the last number of years, filtering through to national policy. Therefore, in order to contribute meaningfully to the ever growing discussion on how to adapt as a nation to the issue of climate change, the Heritage Council and Fáilte Ireland have commissioned this research.

The issue of climate change is a very complex one, covering all areas of life, involving all sectors, and all aspects of the environment. This study has focused on coastal and inland waterways heritage and tourism products, partly due to their vulnerability to impacts of climate change, and partly because of their importance to the tourism industry.

This chapter will outline the methodology used in carrying out this review, before going on to present the structure of the report, along with a brief introduction to the content of each chapter.

#### 1.2 Methodology

This report was compiled from a comprehensive desk-based literature review and consultation with numerous stakeholders with expertise in the areas of natural and cultural heritage, tourism, and climate change predictions and modelling. No primary research has been carried out as part of this review. Full bibliographies have been provided at the end of each chapter.

As part of the consultation process, specialists in various government and non-government organisations, scientific institutions, and the tourism industry were interviewed. A list of consultees is provided at the end of Chapters 5, 6 and 7. Two separate questionnaires, one on heritage and another on tourism (see Appendix A) were generated to provide consistency and focus to the consultation process. Where necessary, and particularly in the area of natural heritage, these questionnaires were followed up by a telephone call. Consultation results were then incorporated into the report.

In addition, a Steering Group was set up to oversee and provide technical guidance to this project. Marine, inland waterways, heritage, and tourism expertise were all represented on the Steering Group (see Acknowledgements for more detail) at various stages of the project.

#### Structure of the Report

This report is divided into 4 main parts:



## **Part I : Introduction and policy overview (Chapters 1 and 2)**

Following on from Chapter 1 (introduction), Chapter 2 goes on to provide a review of existing climate change policy, at an international, European and national level. The purpose of this chapter is to provide a context for the climate change discussion on a number of different strategic levels and to outline what existing and future policy might look like.

## **Part II: The implications of climate change for natural and cultural heritage, and tourism (Chapters 3 and 4)**

Chapter 3 provides an overview of the climate change science upon which the remainder of this report is based. The chapter outlines the climate change phenomena (temperature, precipitation, sea level rise, extreme weather events, etc.) that we are likely to experience over projected future time frames, these being 2020, 2050, and 2080. The authors discuss IPCC global predictions and assess the scenarios for Ireland using the research carried out by ICARUS, at the University of Maynooth.

Chapter 4 looks at some of the physical impacts of climate change, beginning with the potential impacts of climate change on inland waterways, with a focus on rivers. The authors consider the vulnerability of groundwater and surface water-fed river systems, and identify climate change predictions in relation to precipitation and temperature. Physical changes on coastal morphology as a result of sea level rise and storm surges are also discussed. Impacts will vary around the coast depending on the coastline type, with soft coast lines at greater risk. Examples of physical changes to beaches, sand dunes, salt marshes, etc. are identified. Management issues in relation to inland waterways and coastal areas are also discussed.

## **Part III: Implications for natural and cultural heritage, and tourism (Chapters 5, 6 and 7)**

Chapters 5, 6 and 7 form the core of the report, in that implications on natural and cultural heritage and tourism are addressed, based on the findings of Chapters 3 and 4. Whilst Chapter 4 looked at the likely impacts of climate change (flooding, drought, erosion, etc) Chapter 5 builds on this by identifying the implications of these for natural heritage. The chapter introduces basic ecological concepts to explain the links between climate and biodiversity in an Irish context. Today's understanding of the effects of climate change on the natural heritage of inland waterways and coastal waters of Ireland is highlighted. Recommendations for adaptation are also made.

Chapter 6 addresses cultural heritage. The potential implications of climate change on the built and archaeological aspects of marine and inland waterways heritage in Ireland are considered. This includes structures specific to coastal and inland waterways: harbours, piers, jetties, bridges, riverside buildings and quays, lock keepers' houses, harbour and fisheries buildings, lighthouses, coastguard stations, Martello towers, and other fortifications. The archaeological aspects include features and sites found underwater, in intertidal zones, along estuaries, coasts, rivers, lakes and canals. The chapter starts with a brief outline of the main research conducted on this subject and the potential impacts on built heritage and archaeology as identified by international organisations and studies. General recommendations on adaptation and research for Ireland are also made.

Chapter 7 focuses on how climate change may affect tourism and tourism amenities through its impact on Ireland's natural and cultural heritage. It contains an assessment of the likely impacts of climate change on the attractiveness of Ireland as a holiday destination, as well as the likely impacts on visitor enjoyment of their holiday through the range and quality of tourism activities. General recommendations for adaptation are also presented.

## **Part IV: Summary and conclusion (Chapter 8)**

The final chapter summarises the projected changes in Irish climate due to global warming. A summary of the main findings is also provided, and potential future incompatibilities in the areas of heritage and tourism are discussed with examples. Five main recommendations, derived from the preceding chapters, are identified.

## Chapter 2. POLICY CONTEXT

Author: Mary Stack (Fáilte Ireland)

### 2.1 Introduction

The purpose of this chapter is to provide an overview of existing climate change policy at an International, European, and National level. This chapter examines the milestones which have led to existing climate change policy and also examines current negotiations/discussions on future policy post 2012 (i.e. post Kyoto).

This chapter is an overview of climate change policy and contains information taken from three main sources:

- *The Climate Challenge - Strategic Issues, Options and Implications for Ireland* by The Institute of International and European Affairs (2008)
- The policy section of the Government's CHANGE campaign website ([www.change.ie](http://www.change.ie))
- The Intergovernmental Panel on Climate Change website ([www.ipcc.ch](http://www.ipcc.ch))

Additional policy information can be obtained from these sources.

### 2.2 International policy on climate change

While the concept of climate change as a result of anthropogenic activities is not new, political response has been slow. This can be only partially attributed to the lack of consensus in the scientific community as to the science of climate change and the impact on human activity on the environment (IIEA, 2008).

Gradually, international climate change policy has been gathering momentum. This is underpinned by a scientific consensus that climate change is indeed occurring, that it is related to human activity, and that there is a need for urgent action to avoid serious impacts at a global level.

Section 2.2 outlines the major international milestones which have led to formation of current international climate change policy as it currently exists. Three major milestones are considered:

- i. The establishment of the Intergovernmental Panel on Climate Change (IPCC) to provide guidance and consensus on climate change science to policy makers
- ii. The United Nations Framework Convention on Climate Change, established (among other things) to provide the framework for tackling issues identified by the IPCC, and run under the auspices of the Conference of Parties (COP)<sup>1</sup>
- iii. The groundbreaking Kyoto Protocol which came about through the COP

#### *Intergovernmental Panel on Climate Change (1988)*

In 1988 the World Meteorological Organisation (WMO) and the United Nations Environmental Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC). The role of the IPCC is 'to assess on a comprehensive, objective, open and transparent basis, the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation. Review by experts and Governments is an essential part of the IPCC process. The panel does not conduct new research, monitor climate related data or recommend policies' ([www.ipcc.ch](http://www.ipcc.ch)). IPCC reports are accepted as the consensus on scientific opinion on climate change (IIEA, 2008).

The latest and fourth IPCC report was published in 2007. The main findings of this report<sup>2</sup> suggest that:

- Global temperatures are likely to increase by between 1.8°C to 4°C by 2080-2099, relative to 1980-1999
- There will be an increase in the frequency of hot extremes, heat waves, and heavy precipitation events
- Precipitation is likely to increase in mid- to high-latitudes, with reductions in the lower latitudes. Large interannual variations in precipitation are also projected
- Widespread retreat of mountain glaciers will occur. Snow cover is projected to contract with melting of the upper permafrost layer

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<sup>1</sup> The supreme body charged with overseeing the Convention implementation.

<sup>2</sup> Refer to Chapter 3- A Review of Global Climate Change Projections and Likely Scenarios for Ireland for more information on climate change projections.

- Summer sea ice is projected to shrink in both the Arctic and Antarctic. Arctic summer sea ice will disappear towards the end of this century in some model projections
- Globally averaged sea level is projected to rise by between 0.28m and 0.43m by the end of the present century, relative to 1989-1999
- A pole-ward shift in storm track locations is projected. While the number of tropical cyclones per year is likely to decrease, their intensity is expected to increase, leading to fewer but more intense storms
- The Atlantic meridional overturning circulation (MOC), of which the Gulf Stream is part, is very likely to slow down during the present century, with an estimated reduction of 25%. It is, however, unlikely to undergo an abrupt transition during this period

### *United Nations Framework Convention on Climate Change (1990)*

The IPCC's first report in 1990 led to the establishment of an international 'Convention' on climate change, known as the United Nations Framework Convention on Climate Change (UNFCCC). The Convention was established to meet the need to overcome the barriers to communication between countries by establishing an overall framework for intergovernmental efforts to respond to climate change (IIEA, 2008). The Convention established the overall objective of 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'.

The important principle of 'common but differentiated responsibility' was also enshrined in the Convention (IIEA, 2008). This principle is based on the understanding that 'the largest share of historical and current global emissions of GHG has originated in developed countries' and therefore 'developed country parties should take the lead in combating climate change'.

The Convention also established a Conference of Parties (COP) as the supreme body of the Convention charged with overseeing its implementation. The COP meets annually, with extraordinary sessions to be held at other times as deemed necessary. The COP was also given the right to adopt Protocols to the Convention.

### *Kyoto Protocol (1997)*

The Kyoto Protocol, agreed in 1997 (COP3), consolidated the achievement of the UNFCCC by setting legally binding emissions reduction targets. Former commitments under the Convention had no legal status. Annex I countries, due to their historical 'responsibility' and greater economic resources, undertook to reduce their GHG emissions levels by an aggregate 5.2% by 2012. This aggregate target only applied to developed countries, and major emitters were apportioned different targets. The Annex II countries, including major emitters such as China, India and Brazil, were not asked to make any GHG reductions, as had been envisaged in the Convention (IIEA, 2008). It was hoped that the Annex I countries, by acting first, would convince developing countries to follow suit.

The Kyoto Protocol was a groundbreaking initiative in that it also introduced three flexible mechanisms which had the potential to reduce the cost of meeting emissions reduction targets in developed countries. The three mechanisms are Joint Implementation (JI), the Clean Development Mechanism (CDM), and Emissions Trading.

JI is a market based implementation mechanism defined in Article 6 of the Kyoto Protocol, allowing Annex I countries or companies from these countries to implement projects jointly that limit or reduce emissions or enhance sinks, and to share the emission reduction units (ERU). CDM allows Annex I countries to fund emission reduction projects in Annex II countries to offset their own emissions. This allows non Annex I countries to benefit from activities resulting in certified emissions reductions (CER). Emissions trading allows for the transfer of assigned amount units (AAU) to, or acquisition from, other Annex I parties subject to such trading being supplemental and not in place of domestic actions for the purpose of meeting the Kyoto targets.

For a time it looked as though the Kyoto Protocol would not succeed, particularly after the United States president announced in 2001 that the US would not be ratifying the agreement. Despite this major setback the Kyoto Protocol, largely due to the efforts of the EU, has survived. With Russia's ratification in November 2004, the Protocol reached 55% coverage of global emissions which was required and came into force in February 2005 (IIEA, 2008).

### *The Future*

The UN climate change conference in Bali in December 2007 (COP 13), eventually led to the development of the 'Bali roadmap', which set out the course to begin negotiations on climate change post-Kyoto. It is envisaged that a new deal would be concluded by December 2009 at COP 15 in Copenhagen.

## 2.3 European policy on climate change

The European Union has played a significant role in international climate change negotiations, while also displaying an internal leadership among member states on the issue. This has resulted in an overall ambitious level of commitment in the EU to emissions reductions (IIEA, 2008).

### *Kyoto Protocol*

Under the Kyoto Protocol, the EU (consisting of the 15 Member States before May 2004) has undertaken to collectively reduce greenhouse gas emissions by 8% below 1990 levels by the 2008-2012 commitment period. Most of the ten new Member States have the same target (i.e. an 8% cut below 1990 levels), while the target for Hungary and Poland is a 6% cut and Cyprus and Malta have no target (Burden Sharing Agreement 2002/358/EC) ([www.change.ie](http://www.change.ie)).

### *The future*

The development of European climate change policy is similar in most part to how an international policy was reached and has been covered above. However, the EU continues to play a leading role in post-2012 negotiations, and in January 2007 the EU published its *Energy and Climate Change Package*. Within this the EU committed to:

- 30% emission reduction target by 2020 compared to 1990 levels, providing that other developed countries did the same
- A firm and independent commitment to achieve at least a 20% reduction by 2020 based on 1990 levels
- 20% of energy consumption to come from renewables by 2020
- A further objective to reduce emissions by 60-80% by 2050

In January 2008 the European Commission published a package of proposals to act on the 2007 commitments. The package of proposals was made up seven items, many of which are of importance for the development of EU climate change policy post-2012 (IIEA, 2008). These consist of the following:

- A proposal on the revision of the EU Emissions Trading Scheme for the post-2012 period
- A proposal on 'effort sharing' the 20-30% binding emissions reductions (on 1990 levels by 2020) between member states
- A proposal to establish a legally binding target for renewables of 20% of EU energy consumption by 2020, binding national targets and a 10% target for biofuels in transport for all member states
- An impact investment on the emissions and renewables targets
- New guidelines on state aids for environmental protection
- A communication on carbon capture and storage (clean coal)
- An assessment of energy efficiency action plans.

In December 2008 the European Parliament and Council reached agreement on the *Climate Change and Renewable Energy Package*, however implementation is not expected to begin until mid-late 2009 at the earliest (IIEA, 2008).

## 2.4 Irish policy on climate change

### *Kyoto Protocol*

Under the EU 'burden sharing' agreement in meeting the targets set by Kyoto, Ireland has committed to restrict greenhouse gas emissions growth to an increase of 13% over the 1990 baseline levels within the 2008-2012 period.

Ireland's total greenhouse gas emissions in 2006 were 25.5% above 1990 levels, compared to our target of 13%. The transport sector accounted for much of this with a 165% increase since 1990 due to the increased use of private cars on the roads. It is expected that greenhouse gas emissions from transport could increase to 19 million tonnes CO<sub>2</sub>-equivalent, a 265% increase over the 1990 levels ([www.change.ie](http://www.change.ie)).

Greenhouse gas emissions in Ireland have since stabilised but are not showing any downward trend to meet our Kyoto target ([www.change.ie](http://www.change.ie)). For Ireland to reach its target by 2012, the government has set aside €270 million for investment in flexible mechanism projects allowing Ireland to purchase 3.6 million other units for each of the five years in the Kyoto period 2008-2012.

### *National Climate Change Strategy*

In 2000 the Department of Environment Heritage and Local Government published the first *National Climate Change Strategy* (NCCS) outlining the key objectives for reductions in greenhouse gases across the energy, transport, industrial, agriculture, forestry, and built environment sectors.

This second NCCS was published in 2007 for the period 2007-2012. This document sets out in detail how Ireland will meet its commitments to reduce GHG emissions under the Kyoto Protocol. The NCCS set up a carbon fund to administer and manage the purchase of units under the Kyoto Protocol on behalf of the Irish Government. However, the NCCS does not deal in a comprehensive manner with the post-2012 scenario (IIEA, 2008).

### *The Future*

The overall direction of Irish climate change policy will be determined at EU and International level (IIEA, 2008). As Ireland's per capita emissions are the second highest in Europe ([www.change.ie](http://www.change.ie)), and Ireland's GDP is also amongst the highest, it is widely expected that the EU will set Ireland a challenging target, with some suggesting that any attempt at negotiation would be unlikely to succeed (IIEA, 2008).

Any future target will require partnership between all stakeholders - government departments, business, industry and the community - if Ireland is to achieve these goals.

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## Part 2: Climate change: predictions and impacts

### Chapter 3. A REVIEW OF GLOBAL CLIMATE PROJECTIONS AND LIKELY SCENARIOS FOR IRELAND

Author: Rowan Fealy, NUI Maynooth

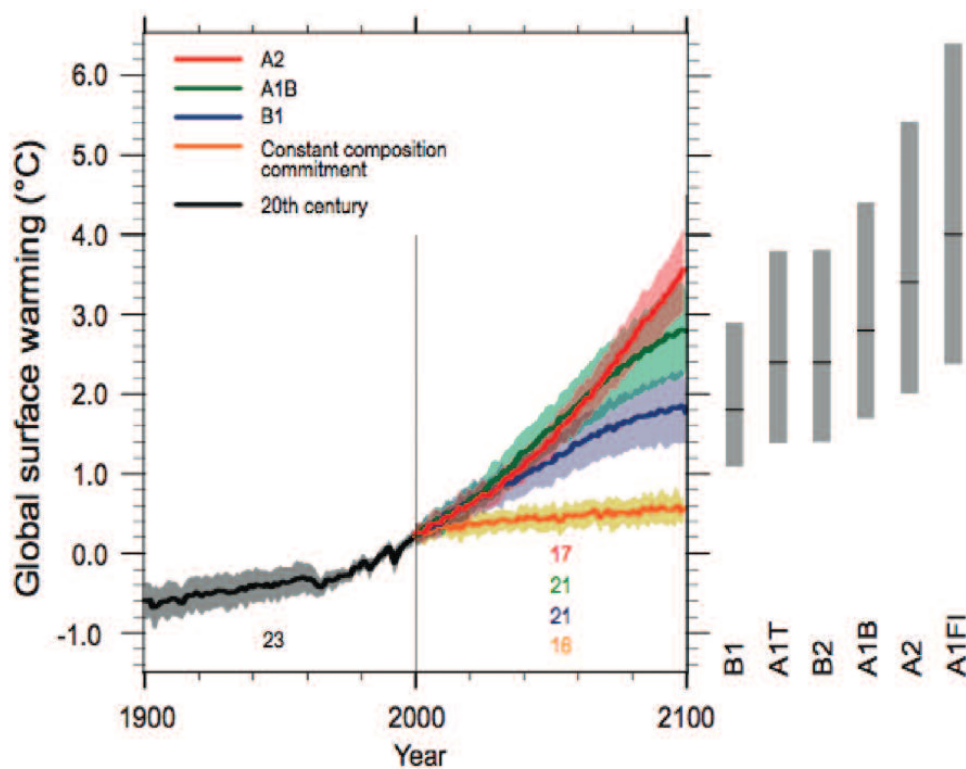
#### 3.1 Introduction

This chapter is a review of national and regional climate scenarios for Ireland within the broader context of the likely global impacts of climate change. Projected seasonal changes in two key meteorological variables - temperature and precipitation - are outlined for three 30-year future time periods: the 2020s, 2050s and 2080s. Changes in extremes of temperature and precipitation are also discussed. This chapter provides the basis for the discussion of the physical impacts of climate change on inland waterways and the coastal environment in Chapter 4.

The latest report from the IPCC, the Fourth Assessment Report (2007a), states that warming of the climate system is now *unequivocal* and that human activities are *very likely* (>90% confidence levels) to be the cause of recent warming. Direct measurements of atmospheric levels of CO<sub>2</sub> since the 1950s show increasing concentrations of this important greenhouse gas (GHG), while anthropogenic methane emissions are currently more than double their pre-industrial levels. Current atmospheric concentrations of CO<sub>2</sub> are over 380 ppm (parts per million by volume) and represent an increase of over 35% above relatively stable pre-industrial levels of 280 ppm. These direct measurements of CO<sub>2</sub> are consistent with ice core data employed to assess atmospheric concentrations prior to the 1950s. Based on ice cores from Vostok Station, in Antarctica, present day concentration levels have not been exceeded in the last 400,000 years nor, most likely, in the past 20 million years (IPCC, 2001).

Even if concentrations of GHGs were maintained at the levels of 2000, warming is likely to continue at a rate of 0.1 °C to 0.2 °C per decade for the next 20 years (IPCC, 2007a). Assuming a continuation of current rates of increase of global anthropogenic CO<sub>2</sub> emissions, a doubling of present day concentration levels is likely to occur by the end of the century. A doubling of the global warming potential (GWP) of all GHGs would occur much earlier. As a consequence, global temperatures are likely to increase by between 1.8 °C to 4.0 °C by 2080-2099 relative to 1980-1999 (Figure 3.1). An increase in temperatures of these magnitudes, if realised, would have a wide range of impacts.

Figure 3.1 Global surface warming for six emissions scenarios (IPCC, 2007a)



Estimates of future emissions are crucial to projecting changes in global temperatures due to increased radiative forcing arising from an increase in GHGs. However, future projections of anthropogenic climate change arising from increased concentrations of atmospheric CO<sub>2</sub> are subject to a high degree of uncertainty (Jones, 2000). As future human behaviour and actions are not predictable, in any deterministic sense, a set of future emissions scenarios are used to provide scenarios of future climate change.

In 1992 the IPCC published the first emissions scenarios, which were the precursor to the present Special Report on Emissions Scenarios (SRES) employed in both the Third and Fourth Assessment Reports (IPCC, 2001, 2007a). These scenarios assume varying levels of future demographic, technological, environmental, societal and economic developments that result in different emissions scenarios for the main greenhouse gases. While over 40 emissions scenarios were developed, four central 'families' (or sets) of equally probable scenarios span approximately 80% of the range of predictions contained in the SRES. Models based on these four emissions scenarios, A1, A2, B1 and B2 (Box 1), will always result in a range of future climate scenarios due to uncertainties inherent in the modelling system (Hulme & Carter, 1999).

#### Description of the SRES emissions scenarios (Source: IPCC, 2001)

The **A1 emissions scenario** describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income.

The **A2 emissions scenario** describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.

The **B1 emissions scenario** describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 scenario, but with rapid changes in economic structures towards a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

The **B2 emissions scenario** describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with a continuously increasing global population at a rate lower than in A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 scenarios. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

### 3.2 Global climate change

Based on these SRES emissions scenarios, projections from a range of global climate models (GCMs) are employed in the Fourth Assessment Report and suggest that significant impacts on the world's climate are likely to occur over the present century. The projected increases in global temperatures are unlikely to be uniformly distributed, with increased rates of warming, nearly double that of the global average, projected for high latitudes. Regional variations in the magnitude and rate of warming will also affect the distribution and rates of change of other meteorological variables, such as precipitation.

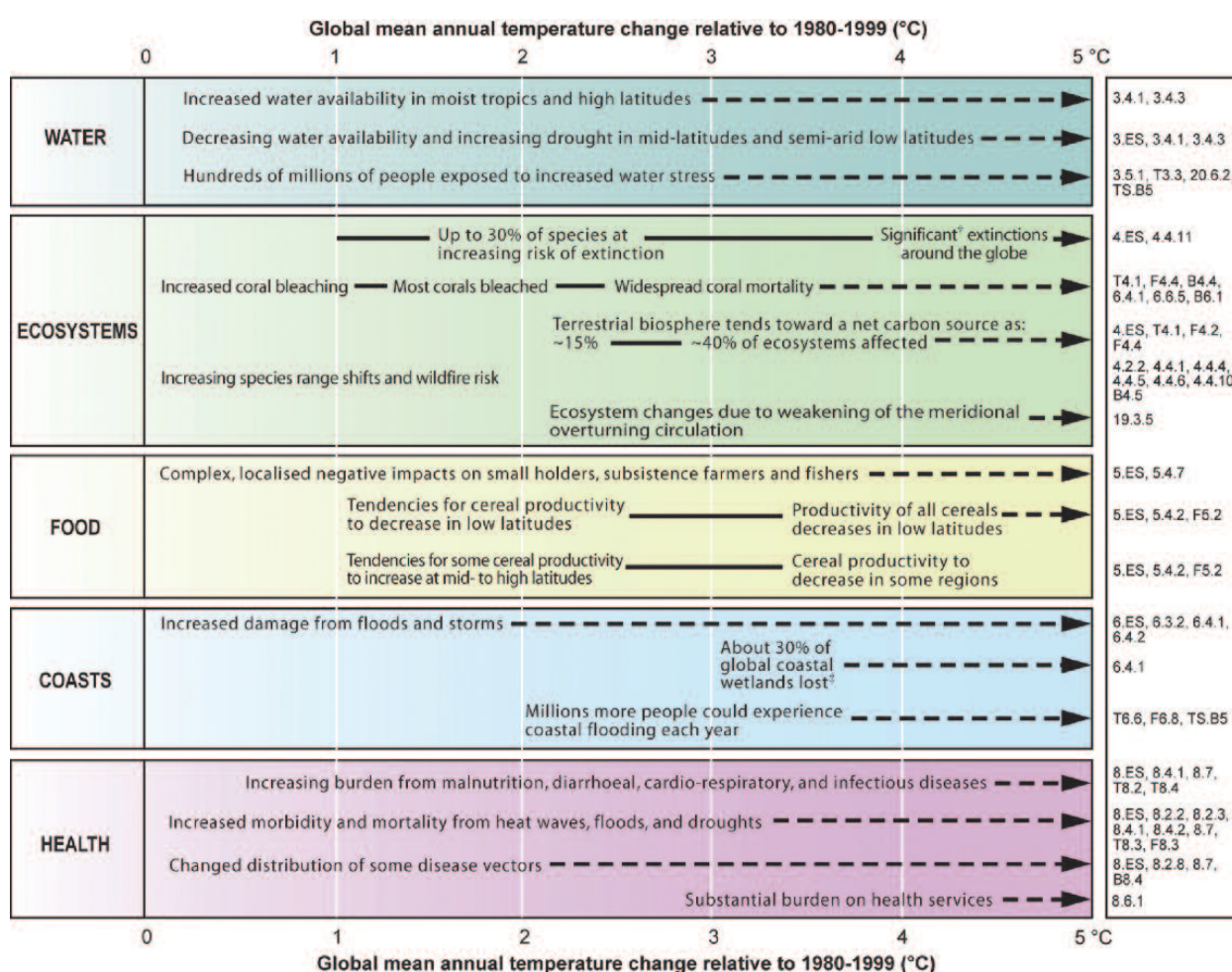
Model projections suggest that:

- Global temperatures are likely to increase by between 1.8°C to 4.0°C by 2080-2099, relative to 1980-1999
- An increase in the frequency of hot extremes, heat waves and heavy precipitation events is very likely
- Precipitation is likely to increase in mid- to high-latitudes, with reductions in the lower latitudes. Large interannual variations in precipitation are also projected
- Widespread retreat of mountain glaciers. Snow cover is projected to contract. Melting of the upper permafrost layers
- Antarctica to gain mass due to enhanced snow fall, while Greenland is likely to lose mass due to a greater relative increase in runoff (IPCC, 2001). Summer sea ice is projected to shrink in both the Arctic and Antarctic. Arctic summer sea ice to disappear towards the end of this century in some model projections

- Globally averaged sea level is projected to rise by between 0.28m and 0.43m by the end of the present century, relative to 1980-1999. (Projected ranges are likely to be conservative, as they exclude important uncertainties in the carbon-cycle feedback)
- A pole-ward shift in storm track locations is projected. While the number of tropical cyclones per year is likely to decrease, their intensity is expected to increase leading to fewer, but more intense storms
- The Atlantic meridional overturning circulation (MOC), of which the Gulf Stream is a part, is very likely to slow down during the present century, with an estimated reduction of 25%. It is, however, unlikely to undergo an abrupt transition during this period (Source: IPCC, 2007a)

Table 3.1 illustrates the projected global impacts in a range of key sectors as a consequence of temperature increases. Due to the projected increase in precipitation, water availability is likely to increase at higher latitudes whereas there will be lower water availability over much of the mid-latitudes and dry tropics (IPCC, 2007b). These changes are likely to exacerbate current pressures posed by flooding and drought in the respective regions. Where moisture availability is not a limiting factor, crop yield potential is likely to increase for global temperature increases of between 1°C and 3°C. Above this threshold, yield is likely to decrease. Large changes in ecosystem structure and function are considered likely if temperatures exceed 1.5°C -2.5°C, with 20-30% of species at risk from extinction (IPCC, 2007b). Changes in the geographic extent of environments are also likely. Coastal ecosystems, such as salt marsh, are particularly vulnerable due to projected increases in sea level, while coasts are likely to undergo significant changes due to both an increase in sea level and the impact of more intense storms. An increased risk of flooding, due to sea level rise, will place hundreds of millions of people at risk, particularly in densely populated, low lying regions (IPCC, 2007b).

**Table 3.1 Projected global impacts for key sectors for various temperature increases (IPCC, 2007a)**



<sup>†</sup> Significant is defined here as more than 40%.

<sup>‡</sup> Based on average rate of sea level rise of 4.2 mm/year from 2000 to 2080.

### 3.3 Regional climate scenarios

Despite the increasing sophistication of global climate models, regional climate projections are still affected by a 'cascade of uncertainty' which results from translating future socio-economic storylines into greenhouse gas emissions and subsequent climate change scenarios. Table 3.2 illustrates the global temperature response ( $\Delta T_{\text{global}}$ ) for the UK's Hadley Centre Global Climate Model (GCM), the HadCM3, and the aforementioned sets of emissions scenarios, A1, A2, B2 and B1 for the 2080s. The regional response for the HadCM3 GCM and four marker emissions scenario is also illustrated, on a seasonal and annual basis for Ireland.

**Table 3.2 Projected global atmospheric concentrations plus global and regional temperature changes for Ireland from the HadCM3 global climate model and four emissions scenarios (data from Mitchell et al., 2002).**

(summer =  $\Delta T_{\text{JJA}}$ , winter =  $\Delta T_{\text{DJF}}$ , annual =  $\Delta T_{\text{ANN}}$ )

Scenario	Concentrations(ppmv)	Label	$\Delta T_{\text{GLOBAL}}$	$\Delta T_{\text{JJA}}$	$\Delta T_{\text{DJF}}$	$\Delta T_{\text{ANN}}$
A1 (A1F1)	970	High	4.8°	3.1°	2.7°	3.0°
A2	856	Medium-high	3.9°	2.3°	2.3°	2.4°
B2	621	Medium-low	3.0°	1.5°	1.4°	1.5°
B1	550	Low	2.5°	1.5°	1.6°	1.5°

Differences arise between various research centres' models largely as a consequence of varying climate sensitivities (change in temperature due to a doubling of CO<sub>2</sub>) and different parameterisation schemes employed by the various modelling centres. It was common practice until recently for many impact studies to employ only one climate change scenario, based on one emissions scenario, derived from a single GCM (see Figure 3.1). Hulme and Carter (1999) consider this practice as 'dangerous', as crucial uncertainties remain suppressed.

While GCMs are adequate tools for assessing the likely impacts of climate change at the global scale, their spatial resolution, which is in the order of ~2.5° x 3.75° lat/long (~250km x 350km at the latitude of Ireland), is generally too coarse to inform impact analysis at the regional scale. As a consequence, a number of *downscaling* techniques have been developed in order to overcome this scale mismatch to produce detailed regional climate scenarios:

- Regional climate models (RCMs), are 'nested' within a GCM but operate on a much smaller spatial domain, therefore available computational resources can be employed to produce climate scenarios at a much higher resolution than their parent GCM. In recent years, the use of RCMs to produce regional climate scenarios has become more widespread due to the availability of high performance computers. However, the spatial resolution of many RCMs is still in the order of tens of kilometres which is still a limiting factor for impact analyses.
- An alternative technique of empirical downscaling has found widespread application due to the ease of implementation in producing high resolution regional climate scenarios. It is a statistical-based technique that does not have the same computational requirements as an RCM, but produces results that are comparable to an RCM.

Research undertaken by the Community Climate Change Consortium for Ireland (C4I) located at Met Éireann, has been based on an RCM and a combination of AOGCMs (Atmosphere-Ocean Global Climate Model) for various future time periods (1950-2100; 2021-2060) (McGrath *et al.*, 2008). However, Fealy and Sweeney (2007; 2008a; 2008b) have employed the alternative technique of statistical downscaling to produce high spatial and temporal resolution climate scenarios for Ireland for the present century (1991-2100).

While spatial differences do exist between the regional climate simulations from both techniques, results are largely consistent in terms of the magnitude of change projected with respect to the key parameters of temperature and precipitation and thus we can have some degree of confidence in the projections. Climate scenarios produced from both C4I and Fealy and Sweeney (2007; 2008a; 2008b) employ a range of GCMs and so cater for some inherent uncertainties arising from differences in climate sensitivity and parameterisation schemes. However, the climate scenarios produced by Fealy and Sweeney (2007; 2008a; 2008b) employed a longer time period for all model simulations and therefore their results are described in greater detail below. Results are presented for three 30-year future time periods centred on the 2020s, 2050s and 2080s, for the ensemble or multi-model average of three GCMs, namely, HadCM3 (Gordon *et al.*, 2000), CGCM2 (Flato *et al.*, 2000) and CSIRO mkII (Watterson *et al.*, 1997), and two emissions scenarios, A2 (Medium-high) and B2 (Medium-low). The difference in temperature and precipitation are presented relative to the observations from the 30-year baseline period of 1961-1990.

Due to uncertainties that arise in climate modelling, individual GCM simulations can vary considerably both in terms of the timing and location of simulated changes. These differences are also reflected at the regional scale, again emphasising the importance of employing a number of GCMs and emission scenarios. Fealy and Sweeney (2008a) found that the greatest differences occurred in the downscaled scenarios for the 2020s period, with one model (HadCM3) projecting a very slight cooling (0.1) during the winter months for this period. Such a value is unlikely to represent a significant change however. Seasons experiencing the greatest warming were also found to differ during the 2020s (Fealy and Sweeney, 2008a). By the 2050s, a greater consistency was found between the downscaled scenarios in terms of the direction of change, however, a difference of almost 2°C was found between the 'warmest' and 'coolest' models. By the 2080s, the difference between the 'warmest' and 'coolest' models was found to be in the order of 3°C (Fealy and Sweeney, 2008a). Similar results were found for precipitation, with both direction and magnitude differences between the individual model projections for the 2020s. By the 2050s, the direction of change was found to be consistent for all seasons, but magnitudes differed between models. A fuller discussion on the downscaled inter-model ranges for both temperature and precipitation are discussed in Fealy and Sweeney (2008a). It is important to note that these model ranges do not account for how well an individual global climate model can replicate the statistics of the observed climate assessed over a common time period and thus, some measure of how 'good' an individual model is required to account for this. The Climate Prediction Index (CPI), originally derived by Murphy *et al.* (2004) and later modified by Wilby and Harris (2006) for application in impacts studies, is one such technique that can account for, or measure, the ability of individual global climate models to replicate the statistics of the observed climate.

Prior to deriving the ensemble means, Fealy and Sweeney (2008a) assessed model differences between the individual GCMs and observed upper air and surface variables based on the Climate Prediction Index (CPI). The CPI produces a weighting for each GCM based on its ability to reproduce the statistics of the observed climate when compared over the 1961 to 2000 period. Models that attain higher scores or weights therefore contribute a greater proportion to the derived ensembles. Ensemble mean changes in temperature and precipitation are quoted in the tables below (Tables 3.3-3.4) along with the unweighted model ranges derived from the downscaled values from individual global climate models. While the unweighted values display a considerable range in values, no measure of how 'good' a particular model is, is accounted for in these ranges and therefore, the value ranges need to be interpreted with great care.

#### NATURAL CLIMATE VARIABILITY

##### Ray Bates (UCD)

Globally, the phenomenon associated with the greatest natural climate variability is the El Niño-Southern Oscillation (ENSO). This consists of the quasi-periodic (3-7 year period) sloshing of warm water from the Western Pacific warm pool eastwards along the equator towards South America, causing anomalous warming of the sea surface over a large area of the equatorial Pacific. The anomaly is so large (locally in excess of 3°C at times) and covers such a large area that it exerts an appreciable influence on the global mean surface temperature. The largest positive ENSO of the twentieth century occurred in 1998 and gave a noticeable peak in the global mean temperature curve in that year. Since then, ENSO has continued to oscillate, but has not since attained anything like the large positive 1998 values. Throughout most of 2008, ENSO was in a negative phase, contributing to the observed dip in the global mean temperature in the year past.

ENSO also has an appreciable influence on the variability of climate throughout the entire Pacific region on the 3-7 year time scale, but it does not have an appreciable influence on European climate variability.

The phenomenon giving the greatest natural climate variability in northern Europe, including Ireland, is the North Atlantic Oscillation (NAO). The simplest measure of this phenomenon is the surface pressure difference between the Azores and Iceland. The NAO varies on time scales from inter-annual to multi-decadal. When the NAO is positive (large pressure difference), the north Atlantic westerlies tend to be stronger than normal, bringing anomalously moist air to northern Europe with cooler than normal temperatures in summer and milder than normal temperatures in winter; when it is negative (small pressure difference), the Atlantic westerlies are weaker than normal and warm dry summers and cold dry winters are more common. Unlike ENSO, the NAO does not influence the global mean temperature.

Scaife *et al.* (2005) have provided evidence that the observed decrease in the number of frosty nights and the change in precipitation extremes in northern European winters in the decades 1965-95 are attributable much more to a trend towards a more positive phase of the NAO than to increased greenhouse gases. It was widely felt for some time that the ob-



served NAO trend was itself a signal of human-induced climate change, but since the 1990s the upward trend in the NAO has reversed, casting doubt on any relationship between it and increasing greenhouse gases.

Scaife *et al.* (2005) have also shown that the ability of current Global Climate Models (GCMs) to reproduce the observed low-frequency variability of the NAO is limited, even when the sea surface temperature and the greenhouse gas concentrations are prescribed. They have shown that the low skill in this area can be improved by prescribing the anomalies in the stratospheric circulation, which is also poorly simulated by the GCMs. An improved representation of the stratosphere may therefore, in time, lead to improved GCM skill in reproducing the NAO variability.

Another feature of natural variability affecting Ireland is the multi-decadal variability (MDV) in the north Atlantic sea surface temperature. Unlike the NAO, which is primarily an atmospheric phenomenon, the MDV is primarily oceanic. It has been estimated by Polyakov *et al.* (2009) that the MDV accounts for 60% of the North Atlantic warming since 1970, the remainder being due to a long term trend that is likely to be human-induced.

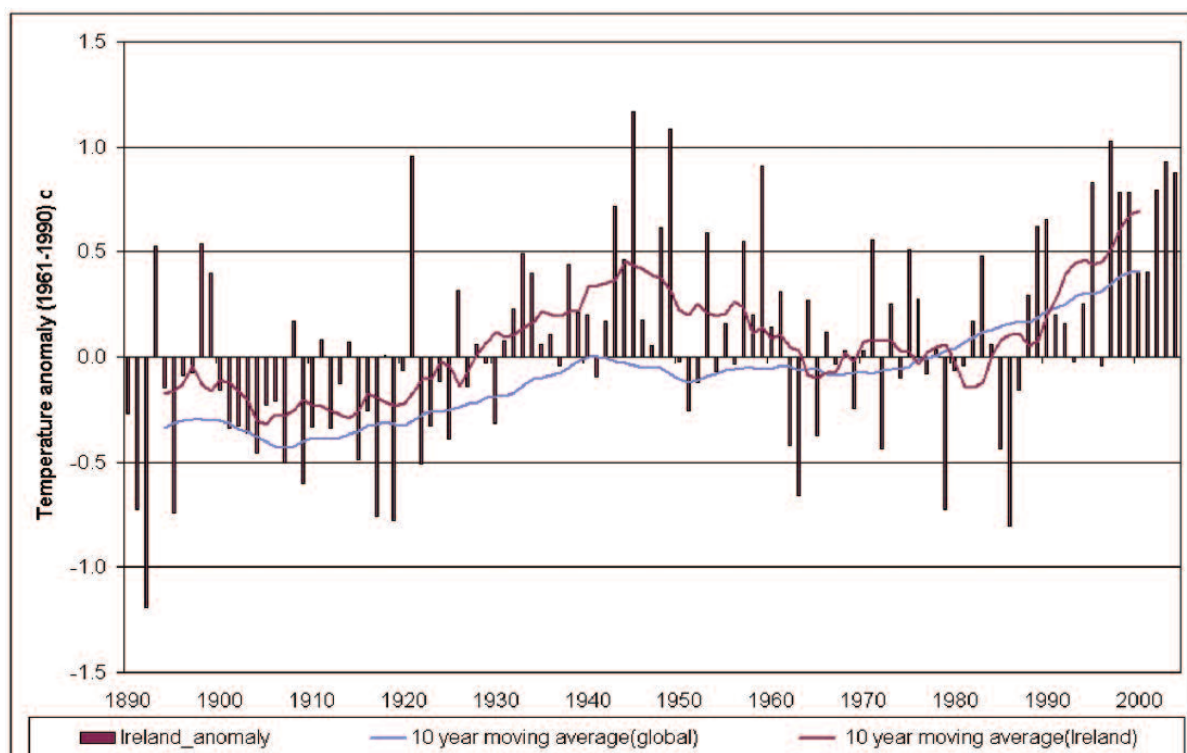
In summary, at our geographic location, large natural variability on the regional scale is superimposed on the emerging signal of human-induced climate change. There can be little doubt that the global average temperature and sea-level rise already show the emergence of the human-induced signal, but for regional climate variables at our location it will be some time before the human-induced signal clearly emerges from the noise of natural variability.

### 3.4 Observed and projected changes in the Irish climate

#### 3.4.1 Temperature

In an analysis of the indicators of climate change in Ireland, McElwain and Sweeney (2007) detected a linear increase of 0.7°C in the Irish temperature records over the 1890-2004 period. Warming occurred in two periods, 1910-1949 and 1980-2004, with the rate of warming in the latter period, of 0.42°C/decade, nearly double that of the earlier period (Figure 3.2). Regional climate projections for Ireland indicate that a mean warming rate of between 0.2 °C to 0.3°C per decade is likely to continue over the course of the present century.

Figure 3.2 Global and Irish Temperature anomalies 1890-2005 (McElwain & Sweeney, 2007)



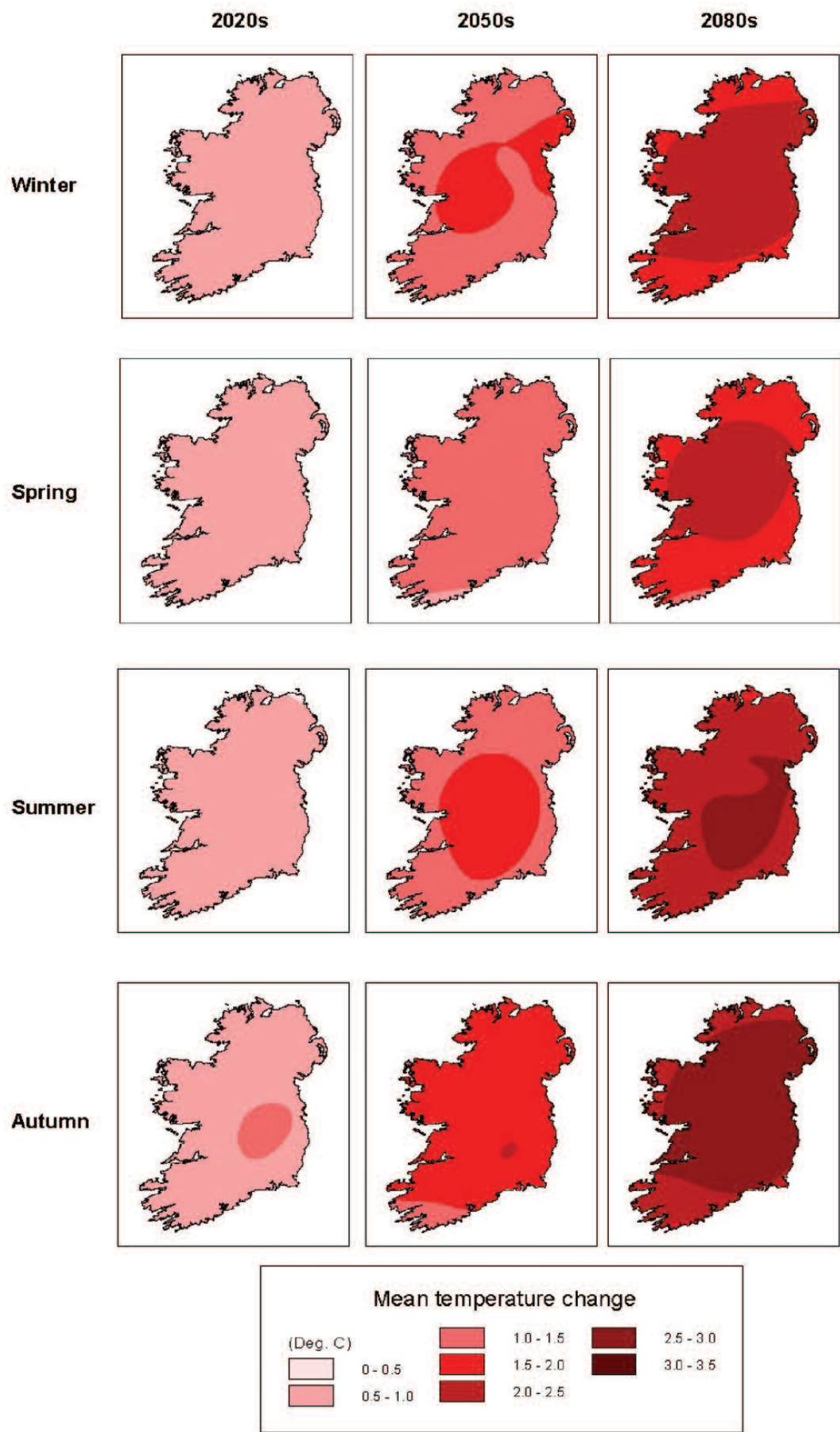
Regional projections suggest that, by the 2020s, seasonal average temperature will increase by between 0.7 °C -1.0°C relative to the 1961-1990 period (Table 3.3) (Fealy & Sweeney, 2008a; 2008b). A warming continental effect also becomes evident during the months of September, October and November, with the largest temperature increase projected to occur in the eastern portion of the Midlands.

By the 2050s, this continental effect becomes further enhanced with mean temperatures projected to increase by 1.4 °C -1.8°C, relative to the 1961-1990 period, with the largest increases occurring in the midland region (Figure 3.3). The greatest warming again occurs during the autumn months, consistent with the earlier projections. The continental effect becomes apparent during all seasons by the 2080s, with mean temperature projected to increase by between 2.1°C -2.7°C.

*Table 3.3 Ensemble mean temperature increases (°C), based on the Climate Prediction Index (CPI), for each season and time period averaged for all stations employed in the analysis of Fealy and Sweeney (2008a; 2008b). Unweighted model ranges are illustrated in brackets. (Fealy and Sweeney, 2008a; 2008b)*

Season	2020	2050	2080
Winter: <i>Dec, Jan, Feb.</i>	0.7° (-0.1 - 1.9)	1.4° (0.5 - 2.6)	2.1° (0.8 - 3.9)
Spring: <i>Mar, Apr, May</i>	0.8° (0.4 - 1.2)	1.4° (0.7 - 2.0)	2.0° (1.3 - 2.5)
Summer: <i>June, July, Aug.</i>	0.7° (0.4 - 1.2)	1.5° (1.3 - 2.5)	2.4° (1.7 - 3.3)
Autumn: <i>Sept, Oct, Nov.</i>	1.0° (0.3 - 1.8)	1.8° (1.1 - 2.7)	2.7° (1.7 - 3.6)

Figure 3.3 Mean seasonal temperature increases projected for the 2020s, 2050s & 2080s



### 3.4.2 Precipitation

Projected changes in precipitation suggest that an increased seasonality (Table 3.4) and a change in the spatial distribution are likely (Figure 3.4) for all future time periods. By the 2020s, mean ensemble changes suggest that winter precipitation is likely to increase by approximately 3%. A similar magnitude decrease in national precipitation is projected to occur during the summer months, although a large regional decrease, of the order of 10-16%, is projected to occur along the south and east coast.

**Table 3.4 Ensemble percentage change in precipitation (%), based on the Climate Prediction Index (CPI), for each season and time period averaged for all stations employed in the analysis of Fealy and Sweeney (2007; 2008a). Unweighted model ranges are illustrated in brackets (values shown are rounded to nearest whole number). (Fealy & Sweeney, 2007)**

Season	2020	2050	2080
Winter: Dec, Jan, Feb.	+3.0 (-4.0 - 9.0)	+12.4 (7.0 - 18.0)	+15.6 (9.0 - 20.0)
Spring: Mar, Apr, May	-1.0 (-10.0 - 4.0)	-7.2 (-1.0 - -14.0)	-8.0 (-25.0 - 6.0)
Summer: June, July, Aug.	-3.2 (-17.0 - 5.0)	-12.1 (-6.0 - -32.0)	-19.0 (-12.0 - -27.0)
Autumn: Sept, Oct, Nov.	-1.7 (-8.0 - 4.0)	-2.6 (-1.0 - -7.0)	-7.1 (-3.0 - -15.0)

Greater seasonality of precipitation becomes evident during the 2050s, with an increase in the order of 12% projected to occur during the winter months. A similar reduction is projected to occur during the summer months (Table 3.4). Regional decreases of between 20-28% are projected for locations along the south and east coasts (Figure 3.4).

These seasonal and spatial changes are further enhanced by the 2080s. An increase in winter precipitation of 15% is projected to occur nationally, with above average increases projected for the midlands. Nationally, summer reductions of 19% are likely, with decreases of between 30-40% along the east and south coasts.

Increases in winter precipitation are projected to occur for all time periods, while reductions are consistently projected to occur for all other seasons. If realised, these changes in the seasonal and spatial distribution of precipitation are likely to result in an increased likelihood of flooding, particularly in the midlands and west of Ireland, while water availability and quality are likely to be adversely affected during the late summer and autumn months in all regions, but particularly along the south and east coasts.

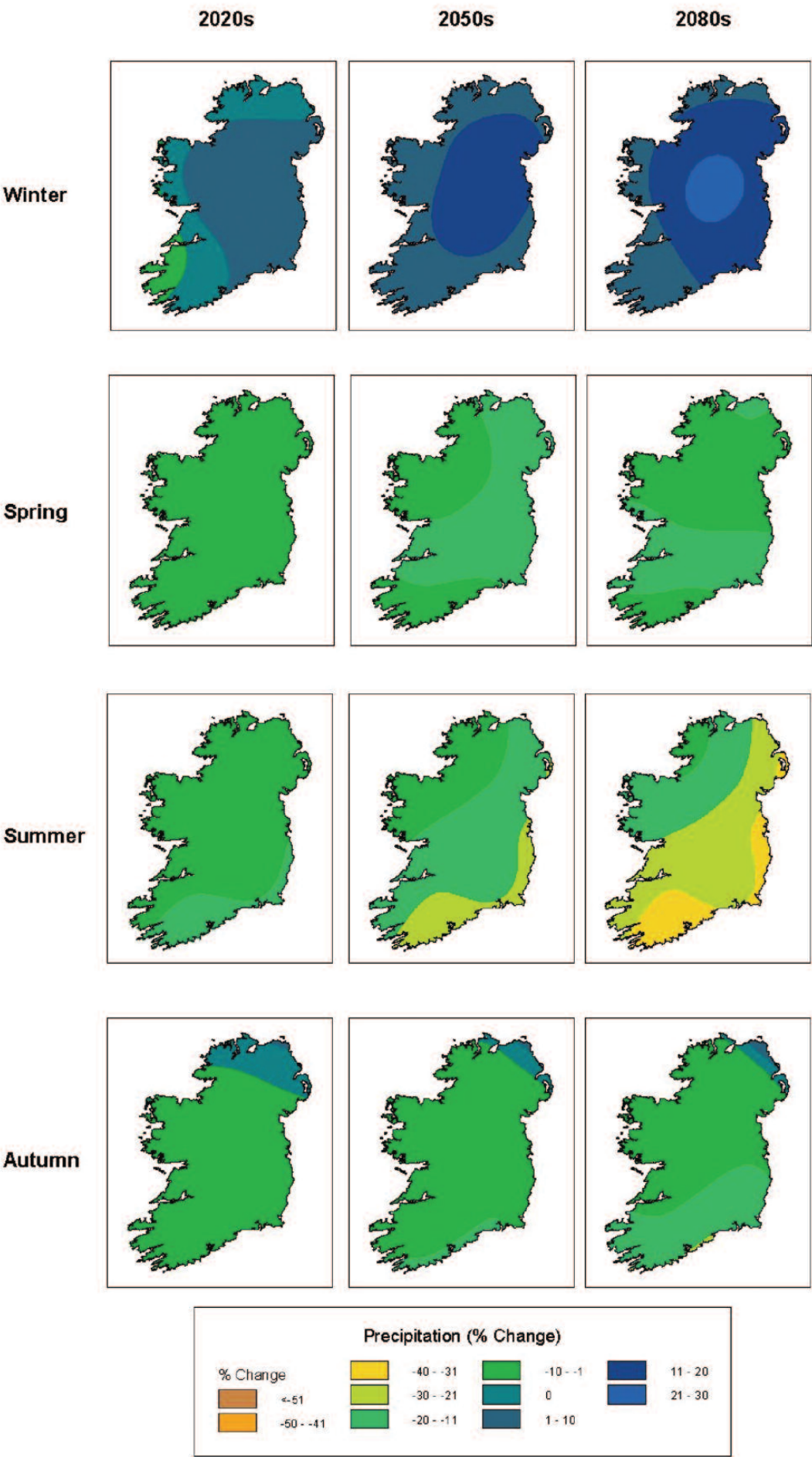
While not directly comparable due to the difference in simulated time periods, spatial differences in projected precipitation are apparent between both the C4I (McGrath *et al.*, 2008) and Fealy and Sweeney (2007; 2008b) simulations for the middle of the century. The C4I simulations (McGrath *et al.*, 2008) project a greater decrease in summer precipitation along the west coast of Ireland, with reductions in the order of 6 to 9%, while the Fealy and Sweeney (2007; 2008b) projections suggest the greatest decrease in summer precipitation will be experienced along the east and south coast. These differences largely reflect uncertainties in the different models and approaches employed and the greater uncertainty associated with modelling precipitation, as compared to temperature, and stress the importance of employing multiple model simulations in order to develop robust adaptation strategies for the future.

### 3.4.3 Extremes: temperature and precipitation

Extremes of temperature (frequency, intensity and duration), with all their adverse effects on human societies and ecosystems, are also expected. The prolonged heat wave that occurred in Europe in 2003, one of the hottest on record, resulted in an excess of 35,000 deaths. In the summer months of 2006 Ireland experienced above average mean temperatures which were nearly 2°C higher than the 'normal' for the 1961-90 period in the midland stations of Clones and Kilkenny. Combined with below average precipitation, this resulted in significant soil moisture deficits through out much of the southern part of the country with resultant impacts on agriculture (Met Éireann, 2006).

A number of extreme precipitation events have been experienced in Ireland in recent years, particularly during the summers of 2007 and 2008 when well above average precipitation amounts and intensities were recorded at a number of locations around Ireland. The extreme precipitation resulted in severe flooding, most notably in Newcastle West in County Limerick and in Mallow, County. Cork.

Figure 3.4 Mean seasonal precipitation changes projected for the 2020s, 2050s & 2080s (Fealy & Sweeney, 2007).





While such extreme events are consistent with the natural variability of the climate system, evidence from the observational records suggests there is a tendency towards an increase in frequency of occurrence and intensity of extreme events. A significant increase was found to have occurred in both maximum and minimum temperatures over the 1961-2005 period (McElwain & Sweeney, 2007). This increase in minimum temperatures has resulted in a shortening of the frost season and a significant decrease in the annual number of frost days (by more than half at a number of stations) (McElwain & Sweeney, 2007). While the number of consecutive cold days has been decreasing over the same period at a number of stations in Ireland, the duration of heat waves has also been increasing,

Fealy and Sweeney (2008a; 2008b), in an analysis of likely future changes in extremes based on the A2 (Medium-high) scenario, found that significant changes are likely to occur in the four key indices of extreme events, namely:

- Hot-day threshold ( $T_{\max}$  90th percentile)
- Cold-night threshold ( $T_{\min}$  90th percentile)
- Number of frost days ( $T_{\min} < 0^{\circ}\text{C}$ )
- Longest heat wave (heat wave duration)

Trends were found to be significant (0.01 significance level) at all stations for all the temperature indices employed in their analysis.

An increase in the intensity of extreme temperatures (the hot day threshold) is indicated for all stations, rising by a rate of more than  $0.2^{\circ}\text{C}$  per decade, particularly for inland stations. An increase in the duration of heat waves is also projected by between 3-4 days per decade, while a decrease in the number of frost days per decade, especially at inland stations, is also likely due to the cold night threshold rising by  $0.2\text{-}0.3^{\circ}\text{C}$  per decade. These projected changes are consistent with the observational records.

As global temperatures increase, the hydrological cycle will become more intense and will result in more extreme precipitation events. Changes in intensity or duration are likely to result in an increase in flood frequency and magnitude, while water shortages or drought conditions are likely due to reductions in precipitation. Analysis of extreme precipitation events suggests a significant and increasing trend in the highest five day rainfall totals at eight of the stations analysed. These stations are located in the midlands and along the east coast. An increase in the longest number of consecutive dry days was found to be significant at all stations, with the greatest increases for stations in the east and midlands.

These changes suggest that Irish precipitation, typically characterised as low intensity long duration, is likely to become more intense resulting in increased surface runoff. Increased surface runoff will have implications for both winter and summer flooding risk, as witnessed during the summer of 2007, the wettest summer on record in over 50 years on the east coast (Met Eireann, 2007).

An increase in the length and frequency of dry periods will also have an impact on water quality and availability and hence an increased vulnerability to water deficits such as those experienced during the summer of 2006. The extremes experienced during these two years could indicate that interannual variability is also increasing.

### Dangerous Climate Change

The stated objective of Article 2 of the UNFCCC is to 'stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. Stabilisation was to be achieved in a time frame such that natural and human systems would have adequate time to adapt. However, the convention does not state what constitutes 'dangerous anthropogenic interference' with the climate system, a deficiency which has led to much procrastination within the scientific and political communities in implementing targets and policies at which stabilisation of GHG concentration should occur.

In 1996, in an attempt redress this deficiency and to limit the severe impacts of global climate change, the EU adopted a climate protection target to limit global mean temperatures to not more than  $2^{\circ}\text{C}$  above pre-industrial levels. However, there remains uncertainty in the scientific community about the sensitivity of the climate system and the equilibrium response of the climate system to a doubling of  $\text{CO}_2$  concentrations. Hence, the  $2^{\circ}\text{C}$  target may be reached at varying levels of concentration levels depending on the actual climate sensitivity of the climate system.



Atmospheric concentrations of CO<sub>2</sub> are currently over 380 ppm (by volume). However, when the global warming potential (GWP) of all GHGs is converted to a CO<sub>2</sub> equivalent, current atmospheric concentrations of all GHGs are over 425 ppm. Globally averaged surface temperatures have already increased by 0.74°C above pre-industrial levels and based on current atmospheric concentration levels we are committed to a further 0.2-0.4°C, resulting in an increase in surface temperatures within the next two to three decades of over half the 2°C protection target adopted by the EU.

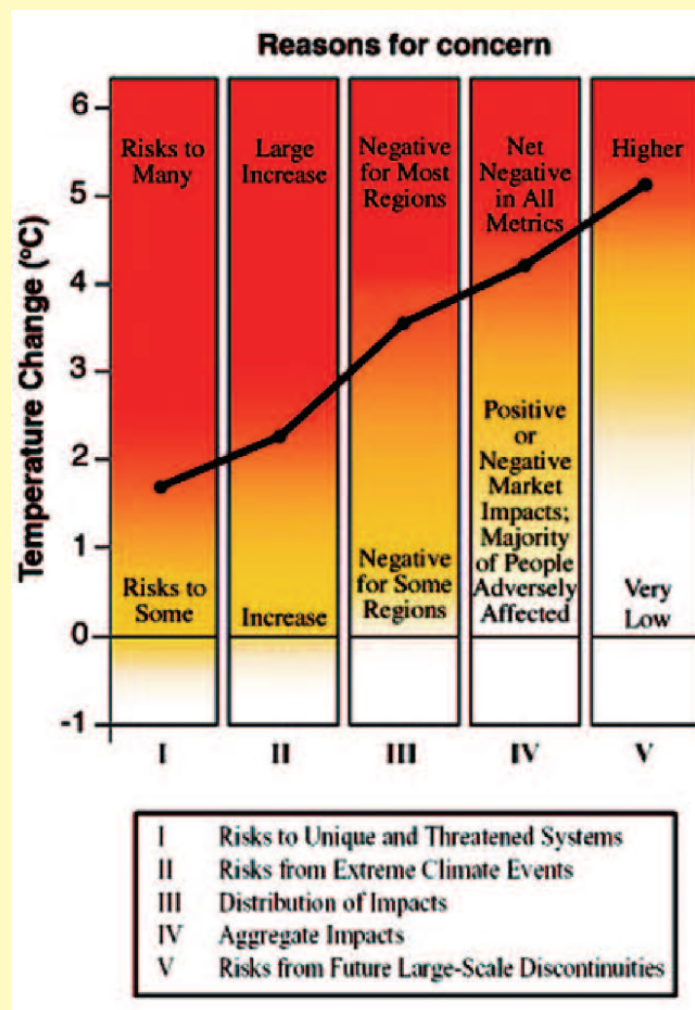
If stabilisation of concentration levels were to occur at current levels, there is a 2 in 3 chance of remaining within the protection guardrail of 2°C. If stabilisation were to occur at 550 ppm, the odds reduce to 1 in 4. Stabilisation at 650 ppm would result in only a 1 in 16 chance of staying within the target (McElwain & Sweeney, 2007).

Table 3.5 illustrates the likely range of impacts associated with various temperature increases above pre-industrial levels. For temperature increases above 2°C, the likelihood of dangerous or catastrophic climate change become apparent. These include increased melting rates of the Greenland Ice Sheet, a slow down of the Thermohaline circulation or Gulf Stream, a collapse of the West Antarctic Ice Sheet and the release of methane clathrates from the ocean floor. The risk of extreme climate events occurring also increases above this threshold (inset figure 3.5).

*Table 3.5 Potential impacts and vulnerabilities for Ireland associated with various global temperature increases (McElwain & Sweeney, 2007)*

Up to 1°C	Up to 2°C	Greater than 2°C
Longer growing season	Increased likelihood and magnitude of river flooding	Sea level rise due to thermal expansion of oceans, melting of the GIS, collapse of the WAIS
Potential for new crops, e.g. soybean	Reduced soil moisture and groundwater storage	Loss of coastal habitats due to inundation and increased erosion
Increased production of existing cereal and grass crops	Water shortages in summer in the east which will impact upon reservoirs and soil management	Increased incidence of coastal flooding
Earlier breeding and arrival of birds	Increased demand for irrigation	More intense cyclonic and extreme precipitation events
Heat stress will have an impact on human and animal health	Change in distribution of plants and animals, e.g. decline and possible extinction of cold Arctic species	
Negative impact upon water quality, e.g. reduction in quantity of water to dilute pollution	Fisheries could be affected as fish stocks are sensitive to small changes in temperature Increased frequency of forest fires and pest infection	

Figure 3.5 'Reasons for concern' associated with various temperature increases  
(Mastrandrea & Schneider, 2004; adapted from Figure SPM2, IPCC TAR SPM of WG II)



There is increasing scientific evidence from palaeo-environmental records to suggest that abrupt changes in temperature have occurred in the past, with large changes occurring over very short timescales. The most documented event occurred during the Younger Dryas (~10,500 years before present), when a freshening of the North Atlantic resulted in a slowdown of the Thermohaline circulation. A widespread and rapid cooling event also occurred ~8,200 years before present, when temperature fell by over 5°C over Greenland for about 200 years.

### 3.5 Conclusion

This chapter presented a review of global climate model projections and likely regional scenarios for Ireland over the present century. While GCMs represent the most appropriate tool for assessing projected large-scale changes in climate, their relevance is reduced at the regional scale for which higher resolution information is required.

To address this deficiency, Met Eireann and ICARUS have employed dynamical and empirical downscaling methodologies to produce regional scenarios for Ireland. While the two modelling centres have employed different parent GCMs, the similarity of climate scenarios implies that we can have a degree of confidence in the respective climate projections.

Based on the downscaled scenarios, significant changes in temperature and precipitation are projected to occur in Ireland over the present century. Warming of greater than 2°C is likely in all seasons by the end of the century, while significant seasonal and spatial changes are projected to occur in precipitation. It is likely that the projected changes in seasonal precipitation amounts and distribution will present a more significant challenge for adaptation than the projected changes in temperature. The review of sce-

narios presented in this chapter only reflect changes in the multi-model average climate simulation, based on the downscaled results from Global Climate Models and two emissions scenarios, the A2 (Medium-high emissions) and B2 (Medium-low) scenarios. In the absence of binding international commitments to mitigate future global emissions, end of century atmospheric concentrations are currently more consistent with the A1 (High emissions) scenario. The results presented here could therefore underestimate future changes in climate for Ireland.

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## Chapter 4. THE LIKELY PHYSICAL IMPACTS OF FUTURE CLIMATE CHANGE ON INLAND WATERWAYS AND THE COASTAL ENVIRONMENT IN IRELAND

Authors: Rowan Fealy and Conor Murphy, NUI Maynooth

### 4.1 Introduction

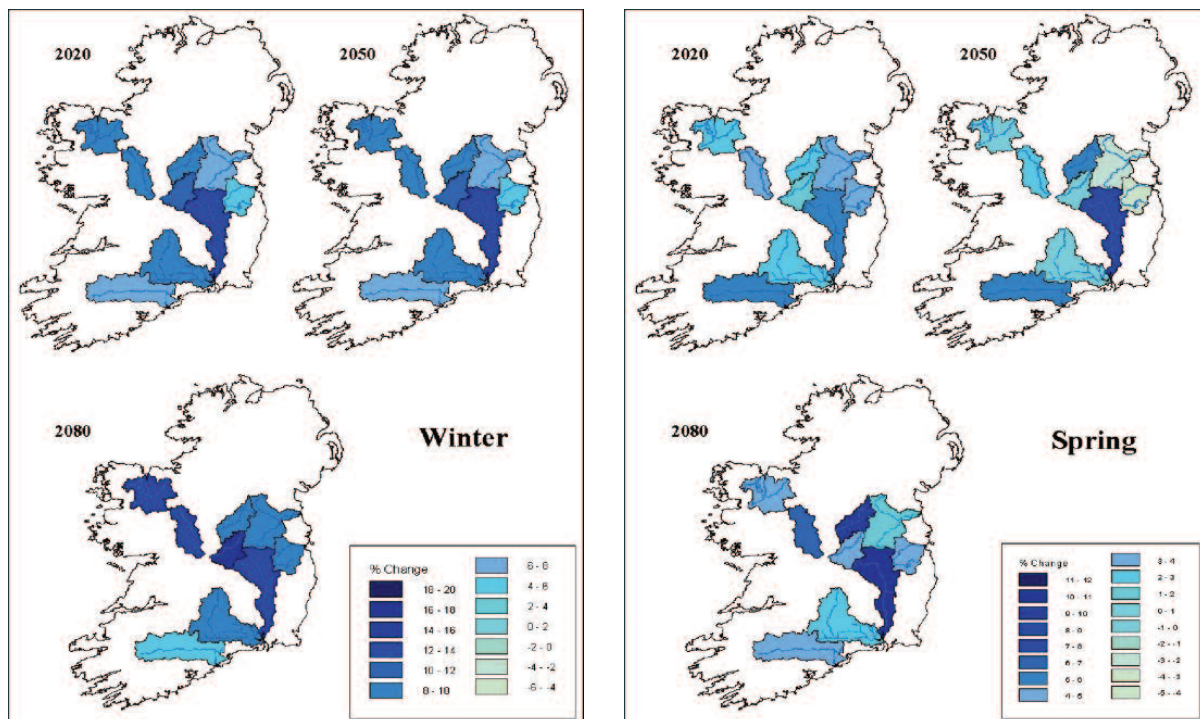
While increasing temperatures in Ireland are projected to occur in all seasons and time periods, it is likely that projected changes in the seasonal and spatial distribution of rain will present a much greater challenge, particularly during the summer months in the south and east of the country. Reductions in summer precipitation, leading to significant decreases in water availability and quality will result in increased competition between municipal, agricultural, and commercial interests, including tourism. Decreases in summer precipitation, together with increased evaporative losses are also likely to affect terrestrial ecosystems, particularly water dependant systems such as turloughs and fens.

Changes in seasonal water levels and the occurrence of extreme high and low flow events will directly impact on river navigability, cultural heritage, and the plant and animal communities of the riparian zone. Inland waterways also provide an important resource for potable water extraction and effluent removal, in addition to providing a tourism and recreational resource.

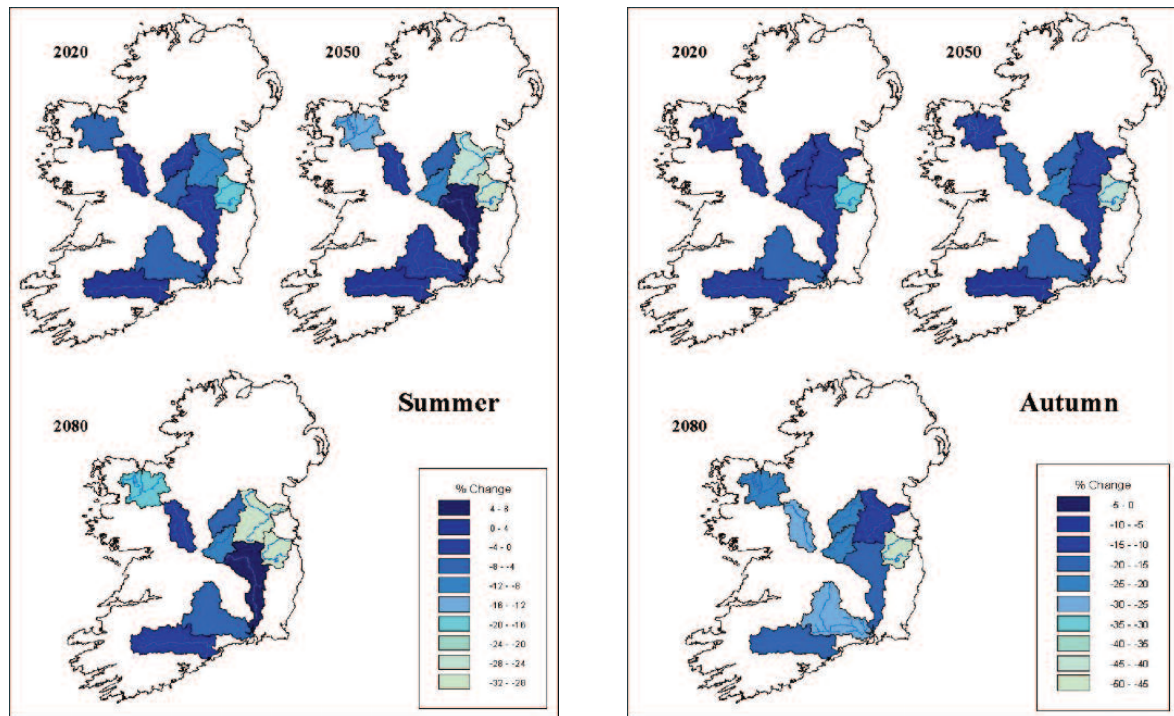
Climate change will also result in changes in sea level, wave energy and storm surges with consequent impacts on the coastal environment, particularly for coastal heritage. These impacts are likely to be further exacerbated due to 'non-climate' pressures arising from increasing population and development within the coastal zone.

In order to determine the likely impacts of climate change on inland waterways and the coastal environment in Ireland, this chapter will present a review of recent research as it applies to impacts in these areas in Ireland.

*Figure 4.1 Seasonal changes in streamflow for selected catchments (Murphy & Charlton, 2008)*







## 4.2 The likely impact of climate change on inland waterway hydrology

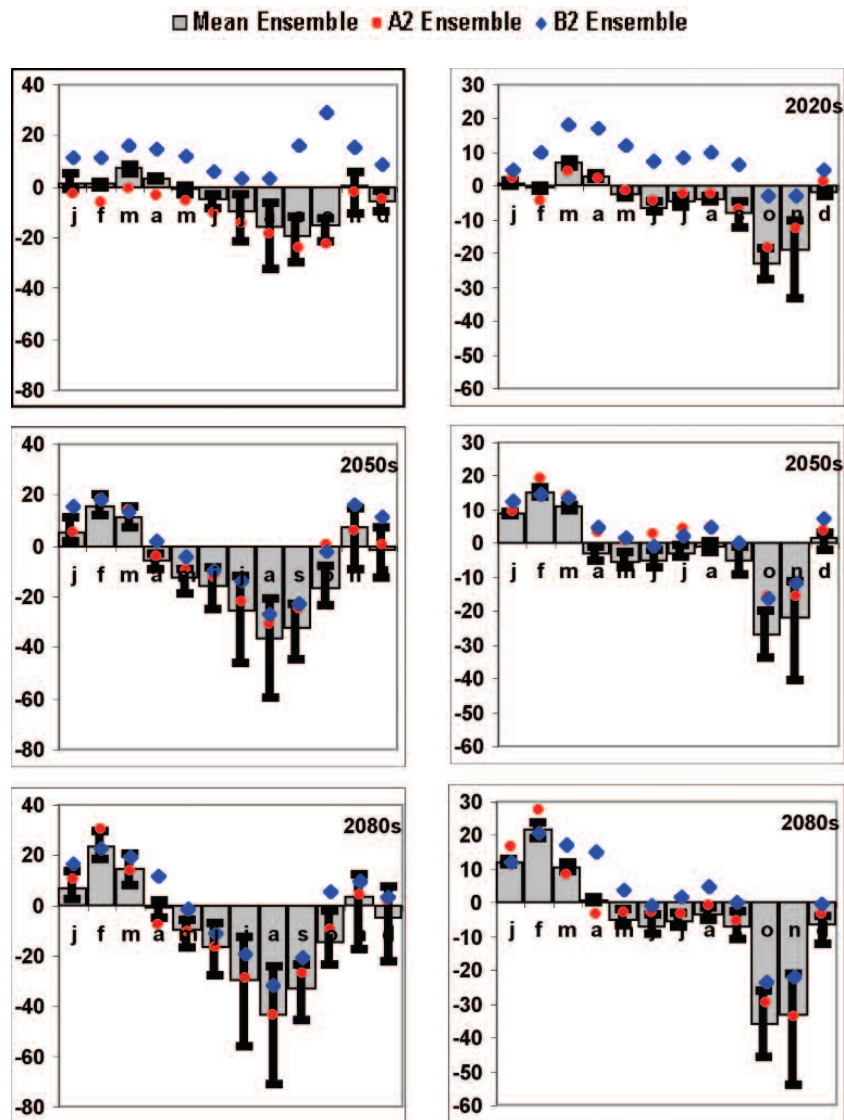
While little, if any, research exists with regard to assessing the direct impacts of climate change on inland waterways in Ireland, recent research has been undertaken by Murphy and Charlton (2008) on the projected changes in stream flow in a number of river catchments and sub-catchments. These include the Rivers Suir, Blackwater, Boyne, Moy, Barrow, Brosna, Inny, Suck, and Ryewater.

In their analysis, Murphy and Charlton employed a multi-model average of climate scenarios, as outlined in Chapter 3, to assess changes in mean streamflow conditions, while individual models and emissions scenarios were employed to illustrate the range of uncertainty. The use of individual models was also employed to assess changes in extremes such as flood magnitude or low flow events, occurrences which could otherwise be muted by the averaging of climate simulations.

### 4.2.1 Projected changes in streamflow

Changes in stream flow result from an interaction between inputs, in the form of precipitation, and outputs through evaporative losses and catchment characteristics relating to soil type, infiltration and porosity. Murphy and Charlton, in their analysis of the impact of climate change on selected catchments in Ireland, identified two distinctive catchment response types to climate change depending on whether a catchment has groundwater storage capacity or is surface water dominant (Figure 4.1 and 4.2).

Figure 4.2 Percent change in monthly streamflow in the (a) Boyne (surface water dominant) and (b) Suir (ground water dominant) catchments for each future time period for the ensemble climate simulation and the A2 (Medium-high) and B2 (Medium-low) emissions scenario (vertical bars indicate the uncertainty associated with the monthly projections of the mean ensemble. (Murphy & Charlton, 2008).



Groundwater dominant catchments like the Suir display lower reductions in summer streamflow due to a compensatory contribution to base flow, in comparison to the more pronounced changes evident in surface dominant catchments (Figure 4.2). However, catchments experienced greatest reductions during the autumn due to the cumulative effect of precipitation reductions in the preceding season, reduced contributions from groundwater to base flow and greater evaporative losses during the autumn months.

Murphy and Charlton suggest that increased flows during the winter and spring are likely, with extended periods of low flows during the summer and autumn months. The result would be increasing seasonality and variability in streamflow (Table 4.1).



*Table 4.1 Percentage change in seasonal stream flow for selected catchments and time periods based on the ensemble climate simulations (after Murphy & Charlton, 2008).*

Year	Season	Barrow	Moy	Suir	B'water	Boyne	Ryewater	Inny	Brosna	Suck
2020	Winter	0.5	2.7	-0.6	0.4	-1.2	-2.0	0.3	1.6	2.8
2020	Spring	5.3	2.0	2.6	5.1	3.1	4.5	2.9	1.9	3.3
2020	Summer	-0.8	-5.8	-4.9	0.5	-10.4	-18.6	-2.7	-5.7	0.4
2020	Autumn	-12.8	-6.3	-16.7	-10.3	-11.3	-33.6	-12.6	-12.2	-11.4
2050	Winter	12.2	8.6	8.5	6.2	6.5	4.7	8.1	10.9	8.3
2050	Spring	7.7	0.1	0.7	5.4	-2.2	-3.4	5.6	-0.9	2.5
2050	Summer	4.7	-14.0	-2.9	2.8	-25.7	-30.7	-7.3	-11.9	-2.2
2050	Autumn	-10.5	-14.2	-18.1	-9.5	-13.7	-41.2	-19.5	-23.9	-19.7
2080	Winter	13.9	12.2	9.1	5.1	8.6	9.0	9.9	16.8	12.2
2080	Spring	10.5	3.2	2.1	3.9	1.4	3.3	10.0	3.1	6.3
2080	Summer	4.5	-19.6	-5.2	-0.3	-29.8	-30.1	-5.5	-9.8	-0.1
2080	Autumn	-18.8	-21.1	-25.4	-18.3	-14.5	-48.8	-22.9	-21.9	-27.1

#### 4.2.2 Changes in flood frequency and magnitude

For selected catchments, using the A2 and B2 emissions scenarios, Murphy and Charlton also assessed the likely changes in frequency and magnitude for four typical flood events of the kind that could be expected every 2 (frequent), 10, 25, and 50 years.

Table 4.2 illustrates the projected changes in flood magnitude based on the A2 (Medium-high emissions) scenario for selected catchments for the three future time periods (refer to Section 3.3). These suggest that the frequency of flood events of given magnitudes is likely to increase as a consequence of climate change. By the 2020s, nearly all catchments display an increase in the frequency of flood events that have hitherto tended to occur once every two years (T2). For example, for the River Barrow, such an event is likely to occur every 1.8 years by the 2020s, while an event hitherto associated with a 50 year return period (T50), is likely to occur with a return period of 12.6 years.

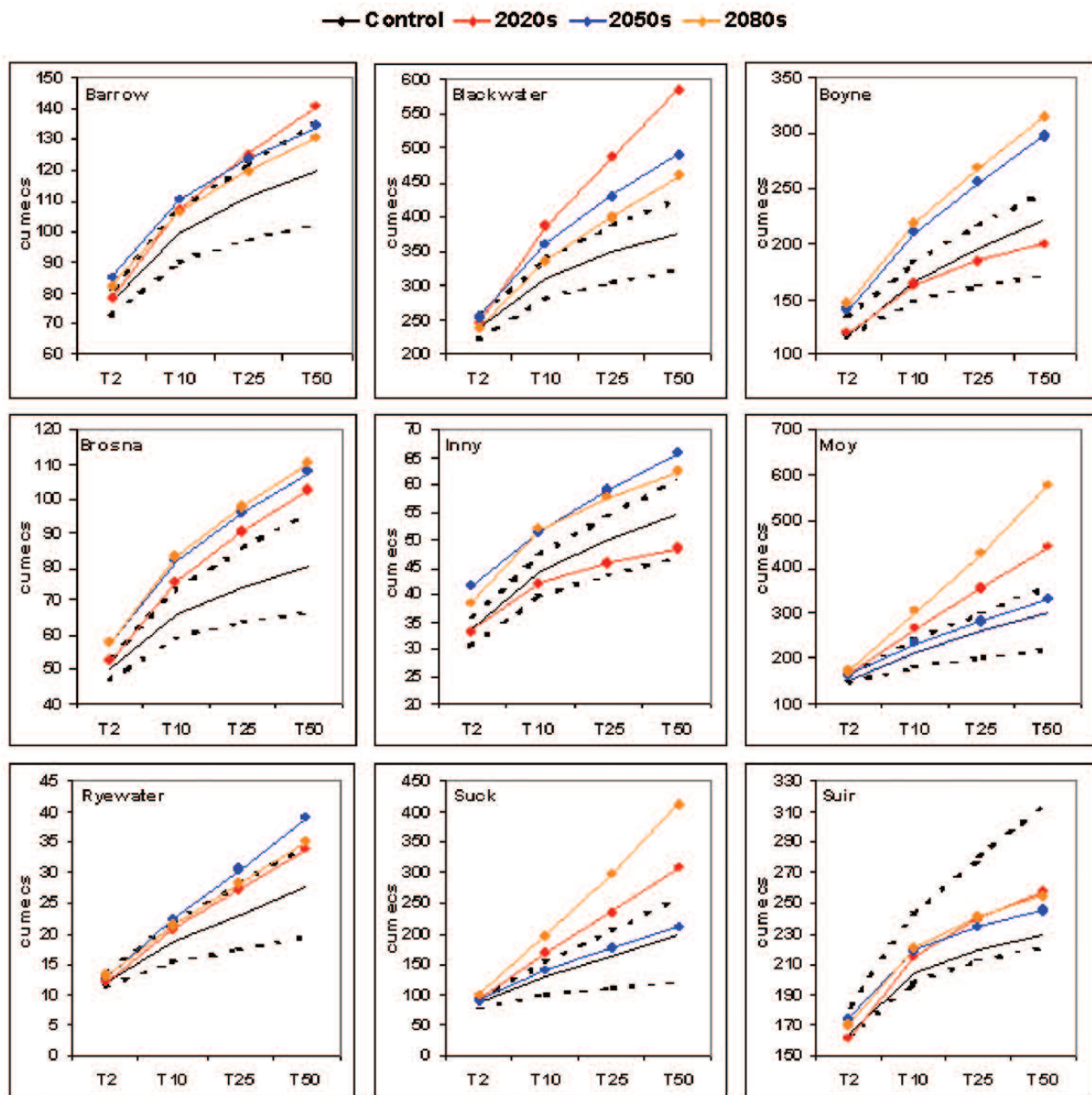
*Table 4.2 Changes in the frequency of floods of a given magnitude for each future time period. Results are based on the HADCM3 (Medium-high) emissions scenarios (Murphy & Charlton, 2008).*

		Barrow	Blackwater	Boyne	Brosna	Inny	Moy	Ryewater	Suck	Suir
	20s	1.8	1.8	1.9	2.1	2.5	1.6	1.6	1.5	1.8
T2	50s	1.6	1.5	1.4	1.5	1.4	1.5	1.4	1.4	1.7
	80s	1.3	1.4	1.2	1.3	1.2	1.3	1.5	1.2	1.5
	20s	12.6	6.5	26.8	85.1	26.4	12.3	7.6	8.8	8.4
T50	50s	18.3	11.1	8.2	6.4	10.6	13.9	8.1	17.8	34.4
	80s	11.5	7.3	2.9	3.8	3.3	4.0	10.2	4.0	6.2

Based on A2 scenario from HadCM3

In addition, simulations based on the same medium-high emissions scenario suggest that the magnitude of flood events is also likely to increase (Figure 4.3) (Murphy & Charlton, 2008). Increases in the future magnitude of floods are significant for most catchments and time periods. The largest increases are projected to occur for the Rivers Blackwater, Moy and Suck.

Figure 4.3 Projected change in the magnitude of flow associated with floods of a given return period (T2- 2-year return period; T50- 50-year return period) under the A2 emissions scenarios( Cumecs cubic metres/second). Confidence limits are shown as dashed lines (Murphy & Charlton, 2008)



#### 4.2.3 Indirect impacts

The simulations conducted by Murphy and Charlton indicate that all catchments will experience decreases in streamflow, most especially in late summer and autumn. The most notable reductions in surface water are simulated for the Ryewater and Boyne. Unfortunately, these catchments are located in the vicinity of the most heavily populated in the analysis. Furthermore, population growth and changing lifestyles will effect new water demands. In studying the impact of climate change on water consumption in the UK, Herrington (1996) suggests that, if unconstrained, a rise in temperature of 1°C would lead to an increase in average domestic per capita demands of approximately 5%. Simulations suggest that demand will be greatest in the summer and autumn when the greatest reduction in surface water resources is also likely. Furthermore, increases in evaporation are likely to result in increased losses from storage reservoirs. Agricultural demand will also be particularly sensitive to climate change.

Navigation on unregulated watercourses is likely to be affected by both high and low flow situations. Floating marinas may have to increase their range of operation to allow for greater seasonal fluctuations in water levels. Low flows during the summer months are likely to pose a hazard for navigation, a situation that is likely to be further exacerbated during prolonged dry periods when an increased abstraction, for potable supplies and irrigation use, is likely.

Water quality is threatened from both the direct and indirect effects of climate change. Direct effects include increasing water temperatures and changes in precipitation intensity together with associated reduction in the dissolved oxygen concentration. Indirect effects include the greater pressure exerted on the hydrological system from increased abstractions and discharges into watercourses. In the Irish context, the greatest effects on water quality are associated with the drier summer and autumn months when reduced water levels are less effective at diluting effluent. Morphological changes will also occur due to changes in erosion, sediment transport and deposition.

#### 4.2.4 Issues for water management

Effective management of our water courses will help to provide defence from extreme events and will be critical to the continued growth in tourism and recreation. However, meeting the challenges posed by climate change is a challenging issue for a number of reasons. Firstly, modern approaches to water management have been founded on historically reactive measures triggered by past or current events, rather than measures based on an assessment of future conditions (Adger *et al.*, 2005). Traditionally such anticipatory measures have been built on the premise that the past is the key to the future. Climate change will mean that past events can no longer be relied on for future decision-making.

Secondly, uncertainty in modelling climate change has major implications for deciding on successful management options (note uncertainty ranges for monthly streamflow in Figure 4.2). In light of these uncertainties, it would not be good practice to base decision making on a single GCM. In such cases, there is a significant risk of over or underestimating impacts. Rather, we will need to use multi-model ensembles that provide representative uncertainty ranges for impacts. There will also be a requirement for industry standard climate scenarios, continually updated, which can be used in advising policy implementation throughout the water sector.

Historically, water management has been largely concentrated on the physical control of water. The recent shift, internationally, towards an integrated assessment of water resources has resulted in a less disjointed approach to management and a move away from site specific hard engineering approaches, to dealing with water management issues holistically at the catchment scale. This shift partly reflects developments at European level through the Water Framework Directive.

The capacity to adapt to greater extremes in hydrological conditions depends on the ability to apply integrated decision making together with technology and systems that are appropriate and sustainable. With this in mind, adaptation should be focused on reducing sensitivity, increasing resilience and altering exposure, through greater preparedness.

### 4.3 The likely impact of climate change on the coastal environment

The present day morphology of the Irish coastline is comprised of a number of different landform types. The west coast is a high wave energy 'crenellate' coastline of high relief and low-lying bays. In contrast, the east and southeast coasts are low-lying and composed of poorly consolidated sediments and glacial tills. Of the total coastline length of 6,500km, approximately 3,100km is comprised of hard coastline with 850km comprised of sandy shoreline (ECOPRO, 1996). The remainder of the coast is generally comprised of cliffs, gravel beaches and barriers, lagoons, saltmarshes, wetlands and mudflats, in addition to manmade structures, such as sea walls.

The west coast of Ireland experiences wave heights of between 2.5 to 3.5m due to the longer fetch of open water over which the wind can act. By comparison, the Irish Sea experiences lower wave heights, of between 0.5 to 2.0m. As wave energy is proportional to wave heights, there is greater energy available for erosion on the west coast, although the rocky headlands act to absorb much of this energy and so provide protection for the adjacent soft coasts (ECOPRO, 1996).

**Table 4.3** Long term (>50 year) erosion rates for various lithologies (ECOPRO, 1996)

Lithology	Rate of recession (m/year)
Glacial till	1.0-10.0
Sandstone	0.1-1.0
Shales	0.01-0.1
Limestone	0.001-0.01
Granite	0.001

Erosion rates vary greatly depending on the structure of landform types and wave energy. Table 4.4 shows the indicative long-term (>50 year) erosion rates associated with various lithologies found around the coast. In a European-wide study undertaken to provide quantified evidence of coastal erosion, Lenôtre *et al.* (2004) found that extensive areas of soft coastline around the Irish coast, particularly in the east, are currently undergoing rapid erosion.

Current erosion trends around the Irish coast may be associated with the significant increase in wave heights reported for the Atlantic between the 1960s and the 1990s. This trend has been linked with an increase in the North Atlantic Oscillation, an index of increased or diminished westerliness, over the same period. Even without a change in wave heights, coastal defences are at risk of being breached or over topped due to changes in relative sea level.

#### 4.3.1 Sea level rise

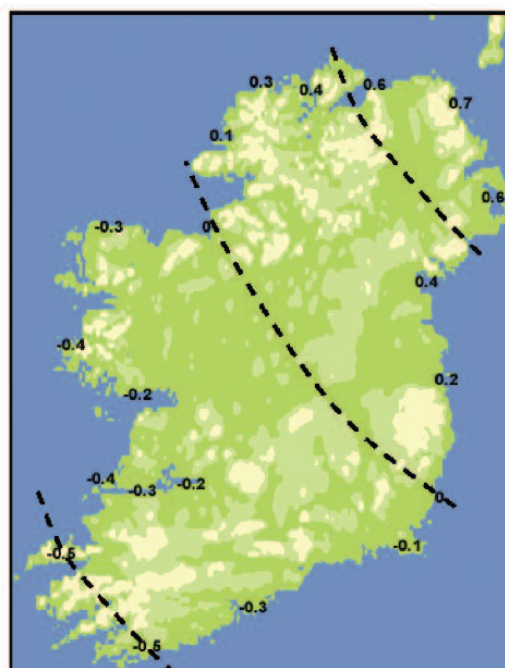
Any fluctuation in relative sea level, i.e. the height of the sea relative to the land, ultimately determines coastal morphology. Globally, sea level has been rising over the twentieth century at a rate of  $1\text{--}2\text{ mm yr}^{-1}$ , resulting in a total rise of  $0.17\text{ m}$ . Over the period 1961–2003, sea level rose at an average rate of  $1\text{ mm yr}^{-1}$ . However, an accelerated increase to  $3.1\text{ mm yr}^{-1}$ , was observed over the 1993–2003 period. Warming of the oceans has occurred to depths of at least  $3000\text{ m}$ , and this, in turn, has resulted in thermal expansion which is estimated to have contributed 13.5% of the rise between 1993–2003.

Continuing thermal expansion together with the gradual melting of the large ice sheets of Greenland and Antarctica, are likely to result in a sea level rise of at least  $0.28$  to  $0.43\text{ m}$  by the end of the present century relative to 1980–1999 (IPCC, 2007a). However, these ranges may be significant underestimates as they do not include important uncertainties in the carbon-cycle feedback. Some researchers, for example Hansen (2007), argue that sea level rise could be much greater, possibly of the order of several metres, due to the non-linear response of ice sheets to warming.

#### 4.3.2 Projected changes in regional sea level around the Irish coast

Determining future changes in sea level around the Irish coast is complex due to isostatic rebound, i.e. post-glacial changes in the elevation of the land relative to the sea. During the last glaciation, a large ice dome was centred on the north of the island depressing the Earth's crust. The melting of this large ice mass during the early Holocene caused the land surface to uplift or rebound. Rebound is continuing with the highest rates in those locations where the greatest mass of ice originally lay, approximately north of a line from north Wexford to south Donegal (Edwards & O'Sullivan, 2007). South of this line rebound rates are slight or negative (Figure 4.4).

*Figure 4.4 Simulated long-term rates of crustal movement (mm/yr) over the last 4000 years. Positive values indicate uplift, whilst negative values indicate subsidence (submergence). (Edwards & O'Sullivan, 2007)*



Eustatic, or global, changes in sea level occur when the volume of water is increased or decreased, such as during periods of glaciation. Global sea level has varied considerably over the last 20,000 years; during the last glaciation it was almost 120m lower than present. The interaction between both eustatic and isostatic changes have resulted in considerable variability in relative sea level around the Irish coast, particularly in the north west of the country where sea level was higher than present between 6,000 to 5,000 years BP. Evidence for these past fluctuations in sea level can be seen in the raised beaches in Counties Antrim and Donegal, the drowned forests found at low tide along the south and west coasts, and peat found along present day shorelines.

Regional projections of sea level rise for the present century are subject to a high degree of uncertainty as warming of the surface layers of the oceans is not likely to be uniformly distributed across the ocean surface. Regional changes in atmospheric pressure and ocean circulation will also affect the distribution of sea level rise (Hulme *et al.*, 2002). As these predictions are based on global projections, under or over estimates of regional sea level rise up to 50% are possible (Hulme *et al.*, 2002).

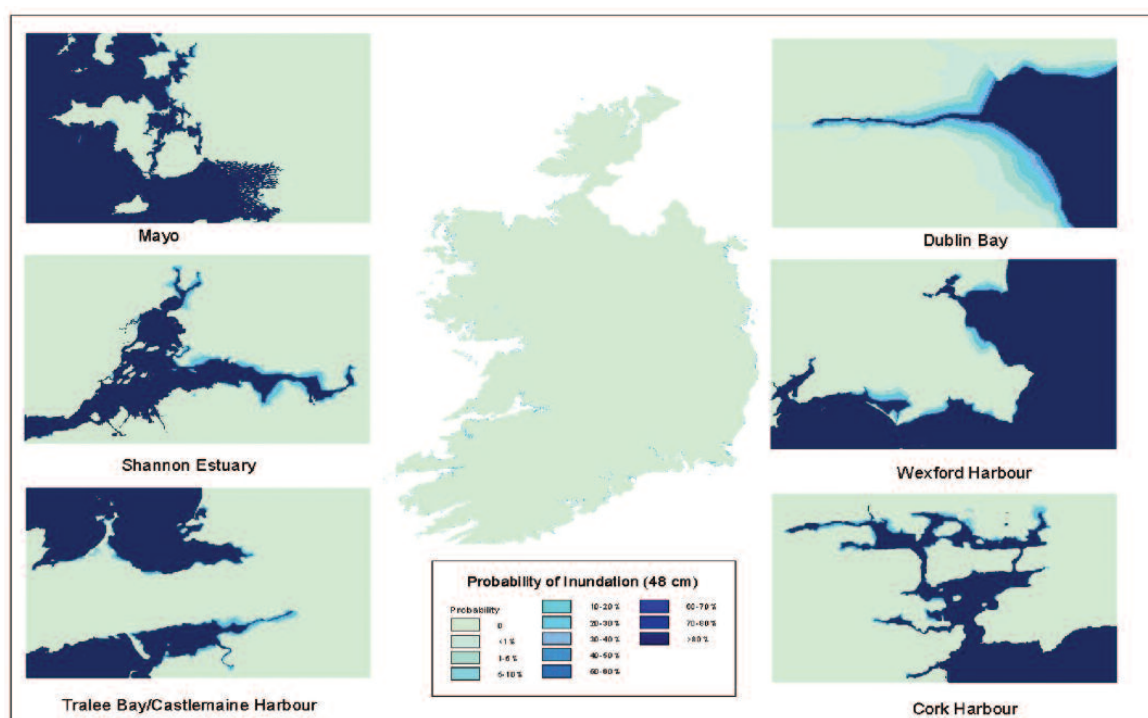
Projections from a range of climate models suggest that globally averaged sea level will rise annually by 2.8 to 4.3mm yr<sup>-1</sup> over the course of the century assuming a linear trend without positive feedback. If a wider range of emissions scenarios is included, a range of between 0.18 to 0.59m is considered more likely. Higher rates of sea level rise cannot be excluded, but our understanding of key processes (such as the response of the Greenland and Antarctica Ice Sheets) means that our ability to quantify an upper value is limited (IPCC, 2007a).

Combining these sea level projections with isostatic rebound rates for Ireland (after Edwards & O'Sullivan, 2007), means that projected rates of relative sea level vary substantially around the Irish coast. For example, locations in the extreme southwest, from the Dingle Peninsula to Cape Clear are likely to experience the largest increases in relative sea level, at a rate of between 3.3 to 4.8mm yr<sup>-1</sup>, while on the north east coast, from Malin Head to north of Dundalk, a rate of between 2.2 to 3.7mm yr<sup>-1</sup> is likely (again assuming a linear increase).

Based on previous estimates of sea level rise (IPCC, 2001), Fealy (2003) calculated the potential area of land likely to be inundated due to a sea level rise of 0.48m, and found that over 380km<sup>2</sup> of the land area of Ireland had a greater than 10% risk of inundation due to sea level rise over the present century (Figure 4.5). While this figure represents a lowering of previous estimates, locations especially vulnerable to inundation include areas with significant land values, such as Dublin, Cork, and Wexford and the Shannon Estuary.

The projected increase in relative sea level is also likely to result in an increase in wave energy being transmitted to the shoreline (Hulme *et al.*, 2002). In addition, coastal locations are likely to be impacted due to changes in rates of erosion and deposition.

**Figure 4.5 Probability of inundation associated with a sea level rise of 0.48 m (Fealy, 2003)**





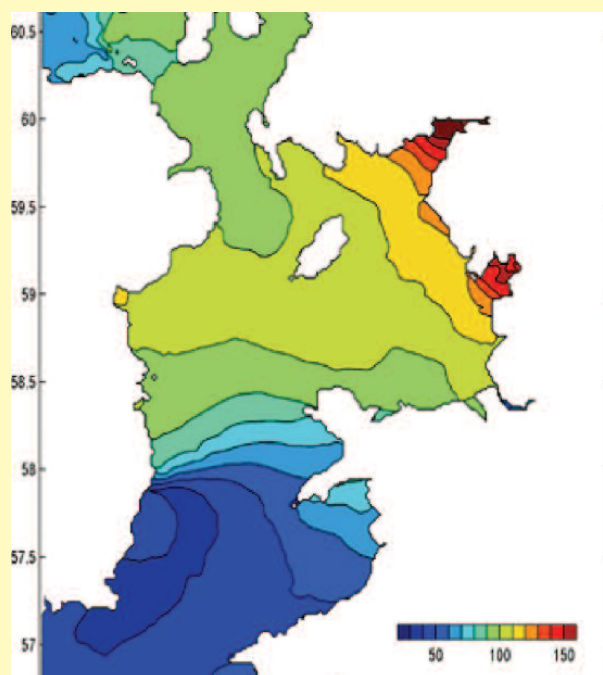
### 4.3.3 Storm surge

An increase in relative sea level over the present century will mean that low-lying coastal areas will be increasingly susceptible to permanent inundation with subsequent changes in erosion and deposition. Temporary changes in extreme water levels resulting from storm surge events (Figure 4.6), particularly if coupled with high tides, are likely to present additional potential for damage through overtopping of coastal defences. Storm surge events can also have a significant and lasting impact on the coastal morphology through the processes of erosion, transportation and deposition.

#### Storm surge 1 February 2002

Significant damage was caused to parts of the east coast of Ireland as a consequence of a severe storm surge event that occurred on the 1 February 2002. The storm surge, which resulted from a combination of several meteorological factors coupled with a high tide, resulted in an extreme water level of 5.46m. being recorded at the North Wall gauge in Dublin, the highest level recorded since records began in 1923. While a high tide had been forecast to occur, the previous days high water level of 4.46m. had passed off without incident. The following extreme water levels resulted from a deepening area of low pressure in the North Eastern Atlantic, which produced gale force south-westerly winds (inset 1). On the Isle of Man, wind speeds reached 50mph, with gusts of up to 70mph being recorded. The sustained winds and long fetch over the ocean, resulted in increased water levels being forced up the Irish Sea (inset 2). These increased water levels or surge coupled with a forecasted high tide, produced extreme water levels over 1m. above expected levels based on astronomical calculations of tidal motion.

*Figure 4.6 Skew surge for the afternoon tide on 1 February 2002 (Proudman Oceanographic). The water height, in centimetres, that exceeded the predicted level.*



Overtopping of the coastal defences lasted approximately two and a half hours, resulting in severe flooding in Clontarf, Sandmount and Ringsend (inset 3). It is estimated that over 300 people were directly affected and required re-housing as a consequence of the flood damage.

Global climate models indicate that it is very likely that tropical cyclones will become more intense, with higher wind speeds and more intense precipitation (IPCC, 2007a). While Ireland is not directly affected by hurricane activity, the remnants of Atlantic hurricanes can be rejuvenated as they pass over the warmer sea surface temperatures associated with the Gulf Stream. If model projections of storm intensity are realised, a significant enhancement of wave heights is likely to occur in the Atlantic. For countries along the eastern Atlantic seaboard, such as Ireland, a rise in surge elevation is likely to increase vulnerability to flooding and storm

damage. An increase in relative sea level will further exacerbate the surge events associated with more intense tropical storm activity.

In an analysis of extreme water levels and sea level rise, Fealy (2003) estimates that 680km<sup>2</sup> of land is at risk of inundation (>10% probability) based on an increase in sea level of 0.48m. together with an extreme water level of 2.6m. representing a 1-in-100 year event on the east coast and 1-in-12 year event on the west coast (Carter, 1991). The return period associated with such an event is likely to shorten as a consequence of sea level rise. For example, the current 1-in-100 year event is likely to become a 1-in-10 year (or less) event.

#### 4.3.4 Likely impacts on the coastal zone

##### *Coastal morphology*

The morphology of the coast is undergoing continual modification in response to the varying forces acting upon it (ECOPRO, 1996). Short-term changes, such as the tidal cycle and wave energy, combine with longer term coastal processes associated with changes in the wave climate, sediment supply and sea level (Charlton & Orford, 2002).

Human activities, such as the removal of beach material or the building of coastal infrastructure, can also have a significant and long lasting effect on the morphology of the coast. For example, Orford (1988) suggests that the twentieth century erosion and shoreline adjustment evident in Rosslare Bay could be attributed to nineteenth century land reclamation activities undertaken in Wexford Harbour. These activities are likely to have resulted in the erosion of Rosslare Spit, shortening its length by approximately 2km.

Discussions of 'hard' and 'soft' coastlines can be misleading. While localised cliff failure due to the erosion of 'hard' coastlines can be dramatic, recent research suggests that the sensitivity of these coastlines, particularly to the impact of high magnitude, low frequency events, such as extreme wave heights, may be greater than previously thought (Hansom, 2001). For 'soft' coastlines, the coastal response to sea level may be self-regulating over short time scales (Carter, 1991). Sediment, such as that stored in dune systems, acts as a reservoir in the exchange between near-shore, beach and dune. Erosion and subsequent removal of this material to sand bars or shoals, may act to diminish incoming wave energy and therefore reduce erosion (Carter, 1991).

In spite of these complexities, a rise in sea level will have an impact on much of the extensive low-lying areas of 'soft' coastline. Figure 4.7 illustrates the variety and type of coastal landforms found around the Irish coastline. These coastal landforms, comprised of silt, mud, sand, peat, gravel or unconsolidated glacial tills, represent fast responding and mobile systems that are highly sensitive to environmental change (Hansom, 2001).

The availability and transport of sediment is central to morphological changes that occur around the coastline (Pethick, 1984; Charlton & Orford, 2002). The sedimentology of the inshore zone is largely determined by the amount of available energy (wave, tidal) and the type of sediment supply. On exposed parts of the coast, where sediments are derived from eroding boulder clay cliffs or from off shore gravel deposits, fringing gravel beaches and shingle banks or storm beaches are formed (ECOPRO, 1996). In more sheltered areas, fine sediments such as muds and fine-grained sands, are common, reflecting the tidal range and lower energy regime (ECOPRO, 1996; Charlton & Orford, 2002).

An alteration in the amount of energy entering the coastal zone, resulting from an increase in sea level, is likely to destabilise existing equilibriums resulting in changes to the coastal morphology, particularly on exposed locations along the coast. Exactly how these will respond depends on sediment supply (Figure 4.8) and the ability of the landform types to migrate landwards. The presence of natural barriers, such as gradient of slope, or man-made infrastructure, is likely to impede landward migration, resulting in 'coastal squeeze'. An increase in sea level will also affect the morphology of landforms which are sheltered from the effects of wind driven waves.



Figure 4.7 Location of coastal systems in Ireland compiled from various sources (after Fealy, 2003)

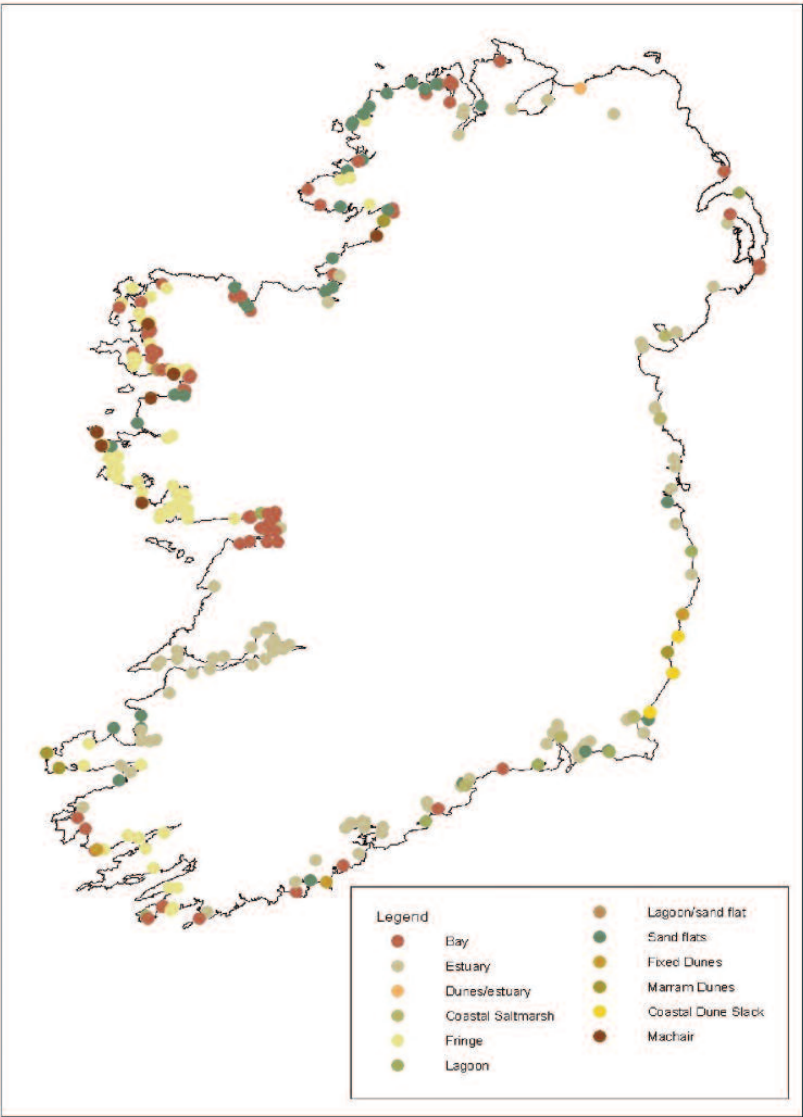
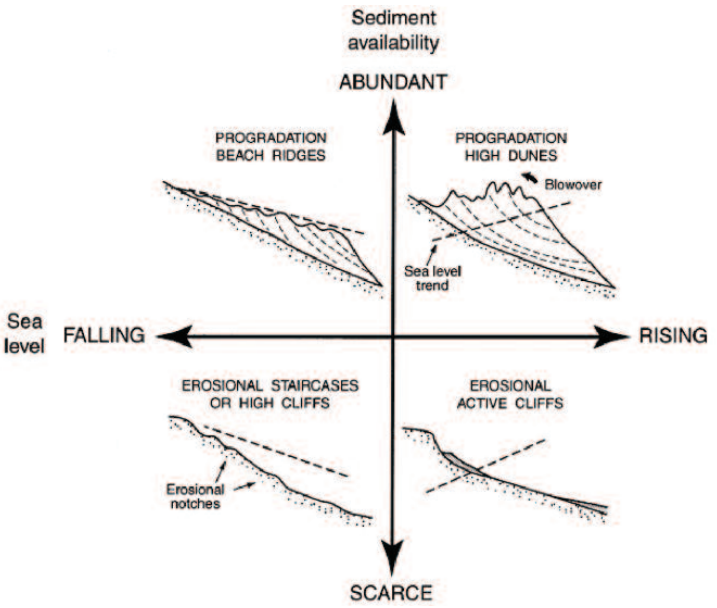


Figure 4.8 Coastal response to sea level rise and sediment availability (Hansom, 2001; after Carter, 1988)



In order to assess the impact of the projected increases in sea level on the morphology of the coast, a selection of landform types is examined in the following section. These range from gravel beaches, associated with exposed, high energy locations, to salt marshes, associated with sheltered, low energy locations and formed of fine grained silts and clays. However, impacts are not likely to be uniform around the coast. Differences in wave energy, sediment supply and other local factors are likely to result in a variety of impacts depending on local conditions (IPCC, 2001).

### *Gravel Beaches*

Gravel or storm beaches are highly mobile geomorphic systems (Carter, 1991) which respond to both seasonal and long term changes in wave energy and sediment supply. During high-energy storm events, material is transferred upslope from the base and seaward face resulting in an over-steepened seaward profile (Charlton & Orford, 2002). Material may also be pushed on to the back slope due to wave overtopping of the barrier crest, resulting in the landward transgression of the beach ridge. Sea level rise is likely to increase the occurrence of wave overtopping, leading to an increased vulnerability of backshore flooding, while increased reworking of the beach material up slope is likely to result in 'roll-over' of the gravel ridge onshore.

Coastal defences designed to prevent over-topping, flooding or to slow the landward transgression, are likely to result in an artificially over-steepened profile increasing the probability of catastrophic failure or break down of the gravel ridge during a subsequent storm event (Charlton & Orford, 2002). Where gravel beaches are impeded from migrating landwards, sediment is likely to be lost through reworking of the sediments along shore (Devoy, 2000).

Back beach lagoons are often formed in the lee of gravel or shingle ridges (ECOPRO, 1996). Lagoons, such as that found on Lady's Island in Wexford (see case study), are designated as a high priority for conservation in the EU Habitats Directive, reflecting their importance as a coastal habitat type that is under threat. Lagoons are likely to be negatively impacted by changes in sea level and storm surges which may result in the penetration of the lagoon barrier, due to reworking of material and overtopping of the barrier (Healy, 1997).

### *Sand Beaches*

Similar to gravel beaches, sand beaches can adjust their shape rapidly to changes in wave energy (Pethick, 1984). During low, flat swell waves, experienced during the summer months, sediment is mobilised on shore, resulting in the beach prograding to form a steep profile. Storm waves experienced during the winter months act to erode the previous season's beach face resulting in a widening of the profile and reduced slope gradient (Pethick, 1984). As a consequence, a beach can maintain a dynamic equilibrium with its environment through changes in its profile that dissipate wave energy.

On much of the south, west and north coasts of Ireland, beaches tend to occupy distinct compartments, or sediment cells, separated by headlands (ECOPRO, 1996; Bird, 2000). Within each coastal cell, the total amount of sediment remains relatively constant but highly mobile. The beach system maintains dynamic equilibrium with the energy gradient through sediment being transported alongshore or exchanged between off shore, beach and backshore storage.

In the absence of an adequate supply of sediment, an increase in sea level will result in a deepening of nearshore waters which will enhance wave energy and accelerate beach erosion (Bird, 1993). Human activities, such as the removal of beach material are likely to exacerbate existing erosion rates. On the other hand, if sufficient material can be supplied through longshore transport, beaches may be maintained or prograded during sea level rise (Bird, 1993).

Where possible, beaches are likely to migrate landwards in response to a higher coastal energy gradient. Sand spits will be increasingly vulnerable to wave over topping and to the flooding of the backshore, although the breakdown of these landforms would provide scavenged sediment to supply downstream locations.

### *Sand Dunes*

Sand dunes, in addition to being features of much ecological interest, protect the surrounding hinterland through the dissipation of wave energy and also help to protect against saline intrusion into the water-table. Sand dunes have an important function in maintaining beach stability through the exchange of material between the dune-beach system (Carter, 1991b). Unlike gravel and sand beaches, they are formed by air or aeolian sand transport.

An increase in sea level is likely to result in the cliffing or scarping of the seaward margins of coastal dunes (Bird, 2000) as is already evident on parts of the Wexford coastline. Where this occurs, strong onshore wind action can initiate blowouts (Ford, 1998).

Landward sediment transfer is likely to facilitate dune migration and the development of transgressive dune fields.

Ultimately, dune response to an increase in sea level will be determined by the amount of sediment transferred to the off shore zone or transferred landward as new dunes.

Over grazing and recreational activities can also significantly damage dune vegetation, reducing the natural resilience of the dune and beach system, resulting in an increased exposure to wind erosion (ECOPRO, 1996). These activities are likely to further expose the coastal zone already made vulnerable by ongoing changes in climate.

### *Salt Marshes*

Salt marshes provide an important ecosystem service through the regulation of nutrients and flood attenuation as well as providing an important habitat for wildlife and fish. They are also sensitive indicators of changing sea levels as they accrete vertically to just below the high water mark (Carter, 1991a). If the rate of vertical accretion can keep pace with increasing sea level, then salt marshes will maintain their position within the tidal range.

Accretion rates of 4-8mm/yr have been found to be occurring on sites along the south and west coasts, linked to increased sediments transfers associated with storm action (Devoy, 2000). These accretion rates may provide some resistance to an increase in sea level, assuming an adequate supply of sediment. Where salt marshes are prograding, vegetation is likely to invade the surrounding hinterland, assuming no barriers exist. Along sections of the coastline where erosion is the dominant process, salt marshes may initially respond positively to an increase in sea level due to increased sedimentation associated with a reworking of material into the inner estuary (Carter, 1991a). However, where low accretion rates occur due to a diminished sediment supply, salt marshes are likely to be submerged and replaced with erosion on their seaward margins.

Salt marshes that occur in areas with a low tidal range are likely to be more vulnerable than those in areas with a larger tidal range. Continued human activities, such as drainage or the building of coastal infrastructure, are likely to further reduce the resilience of salt marshes to the impact of increasing sea levels.

### *4.3.5 Coastal management issues*

The coastal zone is a dynamic system that is sensitive to environmental change. Consequently, a rise in relative sea level is likely to result in modification and spatial reorganisation of the coastal zone. Coastal landforms, which may currently be in equilibrium are likely to exhibit marked changes in response to climate change. Where an adequate supply of sediment is available, coastal landforms may either prograde or migrate landwards in response to a higher energy gradient assuming no barriers exist. If there are barriers, or where sediment supply is limited, erosion of the seaward margins is likely to increase, resulting in 'coastal squeeze'.

In addition to changes in coastal morphology arising from climate change, human activities along the coast can have a significant impact on the coastal morphology. Land reclamation, the building of coastal infrastructure, such as marinas and piers, or coastal defence structures, all act to modify the 'natural' transfer of sediments within the coastal zone requiring shoreline adjustment before a new stable shoreline is achieved. This process of readjustment may take several decades (Pethick and Crooks, 2000).

This displacement of the coastal response, in both space and time, to both climate and human induced changes in morphology presents significant management issues. Implementing effective coastal management is further complicated by the uncertainties associated with the response of the coast to predicted increases in sea level. In order to reduce some of these uncertainties, an understanding of sediment dynamics will be necessary (UK-CHM, 1999).

A number of management strategies exist, which generally involve 'soft' or 'hard' engineering options, retreat/abandonment or a mixture of these. In cases where the retreat of the shoreline is estimated to incur high economic losses, costly reinforcement of existing defences or 'hard' engineering options is normally considered. 'Soft' options such as beach nourishment or dune restoration are usually considered for vulnerable locations with lower associated economic losses. Where the costs of coastal protection exceed a manageable scale or complexity, the 'do nothing' approach often becomes a default management option (Charlton & Orford, 2002).

'Local' actions taken to reduce vulnerability or halt erosion/retreat of the shoreline ignore the larger spatial and temporal context of the coastal sediment budget. They reflect a fragmented view of the coastal system. Such localised interventions may act to ini-

tiate or enhance erosion occurring further alongshore.

### Coastal management in the UK

In the UK, the Environment Agency has responsibility for fluvial flood management. From 2008, its responsibilities will extend to coastal management too. The Agency will have a statutory input to all shoreline management plans, and will assume responsibility for flood risk assessment, coastal protection and coastal habitat.

The responsibilities are huge. DEFRA has estimated that at least €130 billion worth of property is at risk, including industries and infrastructure such as ports, oil refineries, power stations (including nuclear) and power lines. At least 100,000 properties are threatened. This number rises to over 400,000 along the east coast alone should a coastal surge comparable to the 1953 flood disaster coincide with a 0.4m rise in sea levels (Donovan, 2007). Coastal schemes and spatial planning have been required to incorporate potential climate change impacts since 2006. UK planning now requires local authorities to be mindful of a sea level rise of up to one metre by 2100.

Adaptation plans include forward planning and new warning systems, but also higher coastal defence ratings. Hard engineering is anticipated for some locations where infrastructure or towns are at risk. However, the cost of maintaining hard coastal defences will increase due to the combined effect of sea level rise and wave scouring of the beach ahead of defences. On this basis, it has been predicted that the cost of maintaining any one structure in response to a 30cm rise in sea level will multiply by over 180%. Based on a survey of 400 locations, the costs of maintaining coastal defences are predicted to rise by between 28% and 125% depending on whether a low or high emission scenario is assumed (Burgess & Townend, 2007). As a result, the Environment Agency strategy is having to give serious consideration to greater 'coastal naturalisation' and managed re-alignment, the latter to include some level of abandonment.

#### 4.3.6 Adaptation

The NDP 2007-2013 has allocated €23 million to protect the coastline from the impact of flooding and erosion. It is intended that these resources will finance structural works for the construction of Flood Relief Schemes, which "will be implemented in an environmentally friendly fashion, as far as possible".

However, approaches which seek to preserve or protect the present day shoreline are unlikely to represent an optimum long term management strategy for the coastal zone. A more effective management option is one that seeks to manage change in the coastal system so that it is allowed to adjust to environmental or human changes. This requires a high level of understanding of the coastal system supported by effective monitoring of vulnerable locations to identify where and when remedial action is necessary.

Implementing an approach of shoreline realignment, or 'managed retreat', is likely to be contentious where economic losses are possible or where coastal archaeology or tourist sites exist. Nevertheless, the extreme of abandonment may represent the most economic strategy where the cost of implementing coastal defences exceed the value of the structure(s) being protected (Bird, 1993).

Local authorities involved in the planning and development of the coastal zone may need to adopt set back lines, seaward of which no development should be allowed. A precautionary approach should be used to determine these buffer zones taking account of future sea levels, erosion and landward migration of coastal landforms.

There is an urgent need to implement an island wide and integrated coastal zone management (ICZM) policy, the objective of which should be to establish sustainable levels of social and economic activities while still protecting the coastal environment. Cummins *et al.* (2004), in their comprehensive review of ICZM, have made a number of important recommendations in this respect.

The coastal zone provides important economic and recreational benefits to society as well as providing important habitats for plant, animal and fish species. Large parts of the coast are protected under the EU Birds Directive, EU Habitats Directive or the Wildlife Act reflecting the international importance of the coastal zone and the ecosystem services it provides. However, the coastal zone is becoming increasingly vulnerable to socio-economic pressures, particularly from development and over utilisation of resources. Its ability to withstand these pressures is likely to be further compromised by climate change.

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## Part 3: The implications of climate change for natural and cultural heritage, and tourism

### Chapter 5. LIKELY IMPLICATIONS FOR THE NATURAL HERITAGE OF IRELAND'S COAST AND INLAND WATERWAYS

Authors: Marcin Penk, John Brophy, and Roisin Nash (Ecoserve)

#### 5.1 Introduction

Chapter 4 has identified the likely impacts of climate change (temperature, precipitation, storm surges, sea level rise), and building upon these likely impacts, this chapter will look at the implications of climate change on Ireland's natural heritage. For the purpose of this chapter, inland waterways are defined as directly connected surface water bodies: lakes, rivers, streams and canals. Attention is also given to wetlands, considered the most productive of freshwater ecosystems and peatlands, in particular, having the highest risk of being adversely affected by climate change in Ireland (Jones *et al.*, 2006).

Section 2 of the chapter introduces basic ecological concepts to explain the links between climate and biodiversity in an Irish context. Section 3 examines current understanding of the effects of climate change (as discussed in Chapter 3) on the natural heritage of inland waterways and coastal waters of Ireland. The assessment is based on a literature review and on the consultation process carried out in the preparation of this report. A general lack of published information on the impact of climate change on natural systems was identified as one of the deficiencies in Ireland's preparedness for climate change and as a result the section on biological responses draws extensively from personal communication with consulted experts.

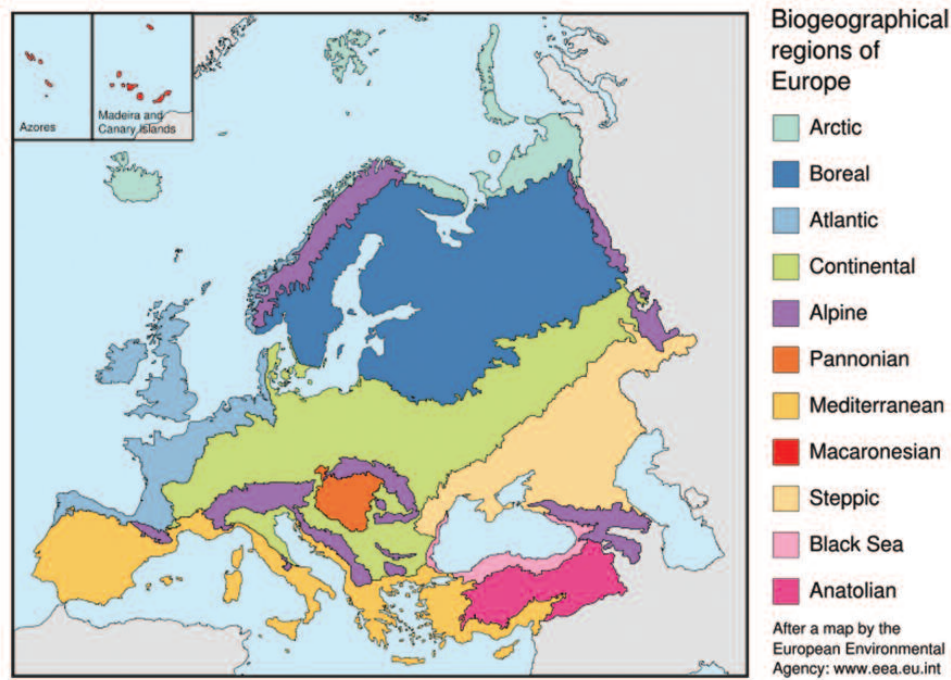
#### 5.2 Climate and biodiversity

##### 5.2.1 Ireland's biogeography

Ireland is a part of the Atlantic Biogeographic Region, which also comprises the Netherlands, the UK and parts of Belgium, Denmark, France, Germany, Portugal and Spain (Figure 5.1). Palaeoenvironmental influences on Ireland shaped the characteristic array of organisms that now comprise its natural heritage. Due to its isolation as an island, Ireland supports a somewhat lower level of diversity of inland species in comparison to continental Europe as not all Atlantic species managed to return after consecutive glaciations. The European Community has established a network of sites under the 'Natura 2000' initiative which aims to provide statutory protection to the representative species of fauna and flora in each biogeographical region. The representative Atlantic Region species and habitats found in Irish coastal and inland waters are protected by inclusion of the habitat or species within a network of Special Areas of Conservation (SAC) and Special Protection Areas (SPA), which offers legal protection not only to them but also to associated species within the communities of which they are a part. In addition, there are a number of designated Natural Heritage Areas (NHA), nature reserves, Ramsar wetland sites, which are of international importance and two World Heritage Sites found within the Irish coast and inland waterways – all of which aim to protect the local fauna and flora.



Figure 5.1. Map of biogeographic regions of Europe.



The waters around the Irish coastline are influenced by the circulatory systems of the Atlantic Ocean, most notably the warm ocean current that originates in the Gulf of Mexico as the Gulf Stream and progresses northeast, becoming the North Atlantic Drift (NAD). As a result, Irish coastal waters are considerably warmer than the global average sea temperature at similar latitudes (Met Eireann, 2008). The average monthly temperature recorded between 1961 and 1990 at Malin Head, County Donegal ranged from 6.7°C to 14.7°C with an annual mean of 10.4°C. The marine territory of Ireland lies between two major biogeographic provinces, namely the Boreal (cold temperate) region to the north and the Lusitanian (warm temperate) region to the south (Hiscock, 1996) (Figure 5.2). Due to the influence of the NAD, the west coast of Ireland mainly supports species typical of more southern waters (Boreal-Lusitanian), such as the sea urchin *Paracentrotus lividus*, the gastropod *Monodonta lineata*, the soft corals *Eunicella verrucosa* and *Parerythropodium corallioides* along with several species typical of northern waters such as the red seaweeds *Ptilota plumosa* and *Odonthalia dentata*. The Irish Sea is generally cooler than the open Atlantic coast and supports a more Boreal suite of species (Emblow *et al.*, 2003) (Figure 5.2).

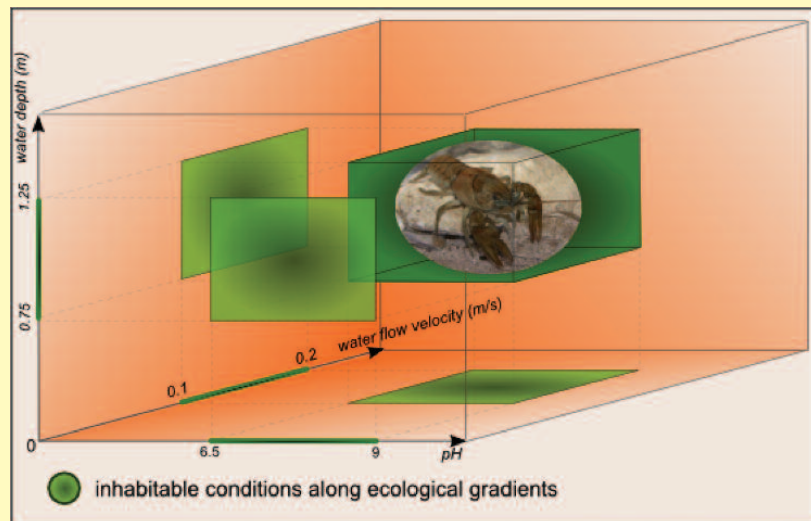
Figure 5.2. Marine biogeographic regions (from Hiscock, 1996).



### 5.2.2 Determinants of species distribution

The distribution of species is a function of a number of variables, both biotic (interactions with other species of fauna and flora) and abiotic (physical environment), together constituting their habitat, or ecological niche. Thus, a habitat is a complex variable comprised of many different environmental factors: temperature, hydrographical conditions, geographic barriers, water quality, substratum suitability, salinity, competition with other species, predation or grazing. These factors are called ecological axes. These axes are largely determined by the main influences which affect the biogeographical region, but even within these biographical regions they tend to display considerable variability. Each species can only survive over a certain range of values along each axis and it is only the confluence of all of the many axes that defines the range of distribution, or its ecological niche.

Ecological niche model using example of white-clawed crayfish



A simplified model of ecological niche with three ecological variables for White-clawed crayfish (*Austropotamobius pallipes*). *A. pallipes* favour pH in the range of 6.5-9.0, water flow velocity of between 0.1 and 0.2m/s and water depth of 0.75-1.25m (Brand, 2007). These values and a number of others not included in this model determine the ecological niche and the suitability of habitat for white-clawed crayfish.

Because of this complexity, it is often difficult to ascertain the species response to a change of a particular factor. Some of the most important determinants of species distribution, listed in a non-hierarchical order are:

- Temperature range
- Hydrographical conditions
- Geographic barriers
- Water quality (temperature, oxygen, pH, etc.)
- Nutrient availability
- Air exposure
- Light availability
- Substratum type
- Salinity range
- Biotic interactions

The physical environment, including the climate, in which a species can thrive is called its fundamental or potential niche. Each species enters a network of interactions within the species community of which they are a part, such as predation, grazing or competition (for space, food, etc.) and these interactions limit the potential distribution of each species to what is called the realised niche (Giller, 1984). Under undisturbed conditions, it is this multidimensional space that is responsible for the species distribution and the composition of their communities. In this scenario, virtually all resources are utilised optimally, providing the biosphere with the maximum output of ecosystem goods and services to sustain aerobic multicellular life, including ourselves. However, this living

space is, in many cases, further limited by anthropogenic pressures, such as pollution, overexploitation of resources or habitat fragmentation. As a result, organisms are forced away from the edge of their ecological niche and optimal performance. If natural resources are not optimally utilised then the array of goods and services provided cumulatively by ecosystems becomes impoverished.

#### Ecosystem services

Ecosystem services are vital to the support of human life and they are provided by natural ecosystems. They include the purification of air and water, detoxification and decomposition of wastes, regulation of climate, regeneration of soil fertility, and production and maintenance of biodiversity, from which key ingredients of our agricultural, pharmaceutical and industrial enterprises are derived.

From a human perspective, ecosystems perform vital services, free of charge, in relation to water supply, food production, nutrient cycling, waste treatment, recreation, climate regulation and many more. These functions are already impaired due to significant impacts from human activities on biological communities and an increase in the concentration of greenhouse gasses (GHG) is likely to create additional problems. Climate change could alter some of the fundamental determinants of species distribution, of which temperature and hydrological regime are of most concern for aquatic ecosystems. Secondary effects will include more variability in water quality resulting from altered hydrology (water turbidity, nutrients, acidity) and altered species interactions.

#### 5.2.3. Responsive reactions of organisms

Climate change has impacted on biological communities through a shift in physical factors, such as temperature, tidal regime, wave exposure, salinity, acidity or substratum alteration. The above factors constitute the fundamental ecological niche of organisms. Indirect impacts are the result of secondary effects stemming from changes in interactions between species in communities altered by physical changes. The responsive reactions of organisms to the combination of both physical and biological impacts are discussed below.

##### *Impact on species*

Each species differs in its behavioural and physiological responses to change. Responses depend on the magnitude and duration of the impact and the species capacity of resistance and recovery. If a given species is not on the edge of its distribution, and its range of tolerance exceeds the habitat alteration encountered, it is likely to acclimatise. This might result in a temporarily poorer performance during the adaptation period, reflected in a less efficient utilisation of resources and lower productivity. However, such a change will not inflict any long-term deleterious effects on the species. If the habitat change persists over a number of reproductive cycles, and it is minor enough as not to push the species away from its ecological niche, the long-term behavioural and physiological changes are likely to induce an adaptation in the genetic makeup of an organism. This will enable the species to gradually return to its optimal performance. However, if a species is already at the edge of its ecological niche limits, or if the change is too overwhelming to allow adaptation, the species will be forced to migrate and move to a more suitable location, thus changing its distribution. If there is no space available for a species to move to, it will face extinction. This might be localised if the species is present elsewhere. However, if the species is rare, it might face ultimate extinction.

##### *Impact on habitats and species communities*

The impacts of climate change on the physical foundations of habitats are discussed in Chapter 4. This chapter deals predominantly with impacts on the living components of habitats, i.e. on species and on the communities of which they are a part.

Evolution is a process which drives alterations to the genetic constitution of species, including their physiology and behaviour. This process can allow species to adjust to each other and adapt to available resources. Different species occupy different ecological niches within biological communities. Under undisturbed conditions the community is in a state of equilibrium when all available niches are filled. This optimises the biodiversity value and, thus, the productive output of the ecological community. Any environmental change exceeding the adaptation capacity of its members is likely to result in species loss. Impoverished biodiversity itself is regrettable, but this will also result in poorer productivity and a loss of the ecological goods and services of which we are among the beneficiaries. Also, species loss creates niche openings, into which other species can move, a situation that has been identified as an important prerequisite for biological invasion.

### Magnitude of impacts

Defining the magnitude of climate change impacts is very challenging as different scenarios are based on fragmented data and uncertain predictions. As a result most impact predictions are made qualitatively.

Communities are dynamic structures and under natural conditions they are constantly subjected to fluctuations in environmental factors. If the impact is **minor**, the result may be a community that temporarily shows poorer productivity or the temporary exclusion of species. At this level, all impacts are reversible and are either within the natural resilience capabilities of organisms or occur in habitat niches that can be quickly re-colonised. However, if the impact is **significant**, it will result in a prolonged effect on communities via the permanent exclusion of species. At this level the changes are irreversible. In the long term, the community might return to a state of equilibrium, but with a different array of organisms and species diversity. Under a **major** impact, large scale species exclusion occurs and community structure changes to the extent that its functional integrity is undermined (Table 5.1).

**Table 5.1. Table of impacts on species and communities**

Magnitude of impact	Impacts at species level	Impacts at community level
minor impact	Impacts are reversible and are either within the natural resilience capabilities of organisms or lead to their temporary exclusion.	Temporarily poorer productivity. Impacts are reversible and occur in habitat niches that can be quickly re-colonised
significant impact	Irreversible changes occur causing permanent exclusion of species.	Prolonged effect on communities. In the long term, the community might return to a state of equilibrium but with a different array of organisms and species diversity.
major impact	Irreversible changes with large scale species exclusion occurs	Community structure changes to the extent that its functional integrity is undermined.

#### Why should we care?

Humans have evolved as part of the natural environment (Costanza *et al.*, 1997). The development of human society from one of hunter-gather to one of land cultivation and industrialisation has gradually created an emotional detachment from nature. As a result people tend to forget that we depend on the goods and services provided by nature for our survival.

These services include waste treatment or water regulation, provision of food, water, and raw material. Costanza *et al.* (1997) attempted to estimate the value of the ecosystem goods and services in terms of providing alternative sources should these be lost. They estimated that this would cost US\$  $33 \times 10^{12}$  per year globally, which is about twice the global GNP estimated by the same study around US\$  $18 \times 10^{12}$  per year. Coastal and freshwater ecosystems were among the most valuable of all examined. More recently, the total value of biodiversity in Ireland has been estimated as approximately €2.6 billion per annum (Bullock *et al.*, 2008). Attempts to replace the ecosystems goods and services by man-made alternatives are costly or indeed impossible.

For instance reedbeds and other wetland plants are known to remove toxins and excessive nutrients from the water (Baker & Maltby, 1995). Society had become aware of the above benefits, as evidenced by the use of artificial wetlands which have been constructed to treat industrial and municipal effluents and run-offs. The value of these services is considerable and technical means to replace them are very costly (Bergkamp & Orlando, 1999).

### 5.3 Biological responses to climate change

The residual impacts of environmental change on the natural heritage are a combination of the effects on species and habitats described above. Effects such as loss of water quality, biodiversity loss, biogeographic shift, and the establishment of alien species are discussed in this section as general impacts. This is followed by a discussion of residual impacts specific to particular water bodies, both within inland waterways and coastal areas.

### 5.3.1 General impacts

#### *Water quality*

Future changes in climate are likely to have significant impacts on water resources in Ireland, which may alter their carrying capacity for many species. More intense rainfall patterns are expected to result in increased runoff. This will carry increased sediment and nutrient loads into waterways, resulting in increased water turbidity and altered nutrient balance. More regular flood events will put increasing pressure on sewage treatment plants in those systems that integrate rainwater runoff. The resultant discharge of excess, untreated material directly into waterways will have a deleterious effect on the ecosystems (Gray, 2004). In addition, saline inundation of coastal freshwater systems will render the affected water bodies unfit to support freshwater fauna and flora.

Altered nutrient input is of particular concern when it occurs alongside a rise in temperature. In enclosed or semi-enclosed waters, where the diluting force of currents is less influential (for instance compared to open shores), it can lead to excess plant and algae growth. The results of the consultation carried out for this report suggest that interaction between increased temperature and eutrophication processes could be critical (e.g. Robert Rosell, AFBI, pers. comm.). Climate change could exacerbate the effects of nutrient enrichment, which is by far the most significant impact of human activity on the freshwater environment and is likely to remain so for the foreseeable future. Reduced water quality will have a profound impact on the drinking water supply in certain areas. It will also render some of the waterbodies unsuitable for certain recreational purposes, including angling. Increased turbidity during heavier rainfall periods can periodically impact on aquatic species and habitats that depend on water clarity. Effects on fish will range from avoidance of highly turbid areas and reduced growth to direct mortality (Cordone & Kelly, 1961, Bisson & Bilby, 1982, Sigler *et al.*, 1984).

The adverse effect of climate change on water quality will be exacerbated by increasing resource and abstraction demands during low flow periods (Murphy & Charlton, 2006).

#### *Biodiversity loss*

On a global scale, it has been predicted that temperature elevation above 1.5 °C- 2.5°C could result in the extinction of 20-30% of species (IPCC, 2007). An extinction of this magnitude would have far reaching consequences for ecosystem structure and function. Ireland is already experiencing large scale habitat loss, especially along the coastline (McElwain & Sweeney, 2006). There are 25 land and freshwater molluscs threatened with extinction in Ireland and, for eleven of them, climate change is a likely contributory cause of future negative impact (Moorkens, 2006).

Habitat loss is of particular concern in coastal areas where the combined effect of sea level rise and increasing storm surges is likely to cause large scale erosion of coastal habitats and saline inundation landwards (IPCC, 2007). The National Parks and Wildlife Service (NPWS) recently reported to the European Commission on the conservation status of Irish EU habitats and species under Article 17 of the EU Habitats Directive. Since the Directive came into force in 1997, losses have been reported in 11 of the 16 coastal habitats, with significant losses (> 10%) in coastal scrub and marram dunes habitats (NPWS, 2008b). Some habitat shift landwards is possible, but might be inhibited in some places by man-made barriers such as urban development and infrastructure. Species confined to these habitats will suffer from a decrease in their range.

More marked water flow fluctuation in inland waterways (see Chapter 4) can alter benthic habitat distribution within rivers and streams. Periodically increased water flow within the watercourses will result in bank erosion threatening marginal habitats. Increased sediment load due to high precipitation events is likely to cause habitat smothering. Gravel habitats, which support a diverse macroinvertebrate community and are important as spawning grounds for salmonids and lamprey, are particularly vulnerable to this impact.

Increased air temperatures will result in mortality of species with low heat tolerance causing reductions in their abundance and/or distribution. This could be particularly detrimental for long-lived organisms and those species characterised by limited mobility. Such species might not be able to re-inhabit previous space in-between consecutive heat events.

Two of the most productive ecosystems may shrink significantly as a result of climate change, namely wetlands and estuaries. The mechanisms responsible for this, as well as expected repercussions, are discussed later in this chapter.



### The Atlantic salmon

Atlantic salmon (*Salmo salar*) is an Annex II species of the Habitat Directive. Total 'one-sea-winter returns' of Atlantic salmon *Salmo salar* to the Irish coast have fallen by 11% relative to 2006 and by 79% relative to 1971 levels. (NPWS, 2008a). While this is a result of many factors, climate change is currently perceived as one of the main threats to Atlantic salmon. Major climate change effects include:

- reduced marine survival because of food chain effects
- reduced survival and growth in summer because of poorer feeding conditions resulting from increased summer temperatures and reduced flows
- possible adult migration delays due to reduced flows and increased temperatures
- decreased spawning success because of increased sedimentation and scouring (Irvine, 2004)

Suspended sediment has a negative effect on spawning, growth and reproduction of salmonids (Sigler *et al.*, 1984, Bash *et al.*, 2001). Inhibitory effects of elevated temperature on egg development were observed under laboratory conditions (Watts *et al.*, 2004). Increases in air and water temperature adversely affect growth of juvenile individuals (Swansburg *et al.*, 2002). The influence of temperature on the survival of 1- and 2-year-old salmon and the distribution of juveniles in the North Sea area is already apparent (Friedland, 1998). Higher peak temperature in the summer months will cause thermal stress and potentially make some sheltered, warmer sites unsuitable during the summer months. Evidence from physiological studies suggests that warmer temperatures would lead to a northward move in the geographic distribution of Atlantic salmon in Europe, with extinction at the southerly edge of the current range (McCarthy & Houlihan, 1997). Ireland is close to the southern edge of the distribution (Froese & Pauly, 2003). While the range of Atlantic salmon range remains favourable, the state of population and future prospects are deemed to be poor (NPWS, 2008a).

Atlantic salmon sustains important recreational and commercial fisheries and these are likely to suffer in future. For example, many rivers in Newfoundland have been closed over a 25-year period (1975 to 1999) because of high water temperatures and low water levels (Dempson, *et al.*, 2001).

### Biogeographic shift

The increase in sea temperatures noted since the mid-1980s has had a pronounced effect on trophic (food) dependencies in marine food webs. Both plankton and fish species have shown northward range extensions since 1980 (Philippart, 2007). There have been major switches in the relative abundance of many marine planktonic taxa during the previous century and these changes were closely linked to climatic fluctuations (Southward & Boalch, 1989, Southward *et al.*, 1995). Many fish stocks are sensitive to small changes in plankton and a northward movement of cold-water species is expected to follow (McElwain & Sweeney, 2006). Perry *et al.* (2005) report that nearly two-thirds of the fish species in the North Sea have already shifted their mean latitude and/or depth compared to the 1980s. This effect will have far-reaching implications for both commercial fisheries and angling.

### The European pilchard

From the 1920s to the 1950s there was a period of sea warming. After 1962 the sea cooled down but since the 1980s regional sea-surface temperature has warmed again (Hawkins *et al.*, 2003). These fluctuations were closely linked to differences in relative abundances of cold and warm-water species. Between the mid-1930s and 1960 there was an increase in the abundance of eggs of European pilchard (*Sardina pilchardus*) in Western English Channel corresponding to warmer conditions and as a result, the spawning stock of this warm-water fish had increased (Southward *et al.*, 1988). This was coupled with much reduced records of other larval fish and plankton invertebrates, perhaps as a consequence of enhanced levels of predation by juvenile and adult pilchard (Cushing, 1961, Southward, 1963). The abundance of pilchard eggs declined during the cooler period of the 1970s, but increased again after 1985 (Hawkins *et al.*, 2003).

Individual species will have different responses and the residual impact at the ecosystem level is hard to predict with certainty. Some of our species are at the northern end of their range in Ireland (palaemon shrimp, spiny lobster, spider crab), while others are at the southern end (cod, salmon). Temperature increases will continue to create more favourable conditions for southern species (BIM Fisheries Development Division, pers. comm.). An overall retreat of species with low tolerance of high temperature is likely to occur. Those species that are at the limit of their range such as Arctic species are expected to decline or become extinct from Ire-



land. (McElwain & Sweeney, 2006). Species such as mysid shrimp (*Mysis relicta*), char (*Salvelinus alpinus*) and pollan (*Coregonus autumnalis*) are known to occur in a handful of locations, where well-oxygenated deep water offers them a cold water refuge. These species are likely to decline and perhaps become extinct from Ireland as a result of climate change-related temperature increases.

The number of Atlantic salmon returning to spawn in North-eastern Europe in general has greatly declined and this appears to be linked to climatic variability as well as to overfishing (Beaugrand & Reid, 2003). The reduction in some species in Ireland, such as cod and salmon, may be partly attributable to climate change as the waters around Ireland are towards the southern edge of these species' distribution (Froese & Pauly, 2003). New fish species and an increase in once rare sightings are recorded in Ireland every year. These sightings have been observed from a south and southeast Ireland gradient and moving northwards. Anecdotal information is also available from fishermen who are catching increasing quantities of species more common in southern waters such as sardines, anchovies, red mullet, bass, palaemon shrimp, spiny lobster and spider crab (BIM Fisheries Development Division, pers. comm.). Elevated sea temperatures, especially at the time of breeding and larval dispersal, are likely to increase the distribution and abundance of southern species and decrease northern species in the future (Hiscock *et al.*, 2004). While it may be hard to predict the long-term impact on the productivity of coastal waters, the above changes will affect the aquaculture and fisheries sectors. (Boelens *et al.*, 2005). Inland waterways are characterised by greater geographical barriers in comparison to coastal areas and they are likely to experience less complex and somewhat slower shifts in biogeographic zones. Nevertheless, changes in the timing of natural phenomena indicating a biogeographical shift have already been observed.

Biogeographical shift will see local ecosystems reaching new equilibriums in which the more adaptive species will replace the less adaptive ones. The survival of those species and habitats that have been evicted by new climatic conditions will depend on alternative space being available to them elsewhere and this might become a problem, particularly in the case of inland waterways.

### ***Alien species***

When species are introduced into a new ecosystem, it must be borne in mind that they have evolved alongside different species than the ones present in the receiving environment. The abundance of a particular species in its native environment is controlled by factors such as natural enemies, presence of competition or food ability. Its dominance within the community is determined by an evolutionary fitness process, through which species adjust to each other and to available resources by long-term (genetic) adaptations. If an alien species is introduced to a new environment, the receiving environment may be lacking the evolutionary-driven ability to control its numbers and the new species may become very successful in colonising this new area. In such a way introduced species become invasive, thrive and outcompete the native ones. In such a scenario certain species or even whole assemblages can face eradication.

However, it has to be noted that not all introduced species become invasive. Some of them may coexist with native species and share the resources, while others will find very little competition and dominate the host community becoming invasive. An additional scenario might see an alien species which had co-existed with other native species for decades turn invasive as a result of environmental change and/or a niche opening.

Changed conditions, especially rapid warming, have facilitated the establishment and spread of alien species such as aquatic plants, alien amphipods, and non-native crayfish. These have already been reported as a 'nuisance' in Britain and Europe because of how they alter food web interactions (Julian Reynolds, Emeritus Fellow TCD, pers. comm.). From a human perspective alien species often cause management problems, an example of which is the fouling of underwater structures by zebra mussel (*Dreissena polymorpha*) or blocking navigation channels as a result of thick growth of various macrophytes. Non-indigenous species have been shown to do better under the warmer conditions experienced in recent years and their spread is expected to accelerate as a result of climate change (Stachowicz *et al.*, 2002).

### ***The Pacific oyster***

The Pacific oyster (*Crassostrea gigas*), which was introduced in north-western Europe for aquaculture, was not expected to reproduce due to the relatively low water temperatures. However, the recent warming, and possible physiological adaptation, has now removed the reproductive barrier and the Pacific oyster proliferates in the receiving environment in the Netherlands and in the UK (Reise *et al.*, 2004). The oyster was introduced to Ireland in 1965. Examination of Pacific oyster from Dungarvan in 1996-1997 detected that it was spawning in both examined years. This was attributed to unusually high sea temperatures (Steele & Mulcahy, 1999).

### 5.3.2 Inland waterways

Climate change has impacted on inland waters through increases in water temperature, and other effects linked to longer dryer summers and increased runoff into the waterways during higher rainfall periods. The residual impacts will differ significantly between standing and running waters and these, as well as impacts on wetlands, are discussed below.

Figures 3.3 and 3.4 in Chapter 3 above, considered how regions of Ireland will experience differing rates of climate change. However, biological impacts on individual standing and running water bodies depend on catchment characteristics rather than on geographical location and pronounced differences are predicted even for neighbouring catchments (Figure 4.1 in Chapter 4).

#### *Standing waters (lakes and ponds)*

Greater variability in rainfall amplitude, and therefore water levels, will lead to a more variable immersion regime for animals and plants inhabiting areas close to water margins. Shore vegetation, which plays an important part in the life cycle of emergent insects, might be affected by more variable water levels. This will result in altered species composition, with species which are more adapted to fluctuating water conditions becoming more abundant (Caldow & Racey, 2000). Littoral invertebrate fauna are likely to be exposed to a greater degree of periodical desiccation (drying up), potentially leading to a decline in their abundance and promoting the survival of more resistant, opportunistic species assemblages with impoverished biodiversity. In addition, some invertebrates are very sensitive to temperature changes and this can impact on their reproductive success and survival. Invertebrates play a vital part in nutrient cycling and are the main source of food for fish and changes in water levels have a significant negative effect on their communities (Caldow & Racey, 2000). The shallows of inland waterways (littoral zone) are known to be the most productive and most biologically diverse areas of lakes (as opposed to the deeper parts), mainly due to light availability. Thus an impact on littoral invertebrate communities significantly affects the functioning of the whole water body.

Should temperatures continue rising, a change in fish species abundances will be apparent, for instance, salmonid fish could decline and coarse fish could increase (Robert Rosell, AFBI, pers. comm.). Eutrophication is likely to become a more common problem as a result of higher temperature and periodically elevated nutrient load, possibly leading to more severe oxygen depletion. This will affect the amenity value of lakes for humans with certain waterbodies becoming unfit for swimming or angling or simply become unpleasant due to more frequent algal blooms, etc. Aquaculture industries, such as salmon farming, might become economically unviable in certain locations.

#### *Running waters (rivers, streams and canals)*

Upland headwaters and middle river reaches may be particularly sensitive to climate modification, as their water flow dynamic is more sensitive to precipitation (Conlan *et al.*, 2005). However, the impact of flood events might be also evident in lower reaches of some watercourses, as river channels and floodplains tend to be modified. This adversely affects their water storage capacity and allows water to drain down the catchment more rapidly (Bergkamp *et al.*, 1999, Sweeney *et al.*, 2003).

An increase in the occurrence of river flooding is expected during winter months. In turn, the summer is likely to see more droughts resulting in a low water flow. This will significantly alter the hydrology of river habitats and will result in an increase in the number of temporary streams (Sweeney *et al.*, 2003). Altered stream hydrology will change physical stresses on the benthic habitats which have been identified as one of the most important factors (axes) responsible for distribution of invertebrates. For example, Méricoux & Dolédec (2004) noted that the proportion of filter feeders and collector-gatherers is closely related to physical stress of the water current. Marginal habitats will be more vulnerable to the eroding force of water during high flow periods and direct habitat loss due to damage and/or removal of the river bank will result (Ormerod & Watkinson, 2000). The effects of a more variable stream hydrology regime can also be exacerbated by wetland loss. Wetlands play a crucial role in water regulation, retaining excess water during high flow periods and gradually releasing it into the watercourses under dry weather conditions. This water regulation capacity is being undermined in Ireland as a result of arterial drainage and other human activities (such as infilling, dumping, and land development).

Increased erosion will lead to a higher input of nutrients, greater turbidity, and increased habitat siltation. A number of indigenous species of conservation importance (such as white-clawed crayfish, *Austropotamobius pallipes* or Atlantic salmon *Salmo salar*, both Annex II species of the Habitats Directive) might find it harder to locate suitable spawning grounds or refuges. Watercourses are also likely to experience periodic fluctuations in nutrients levels, although their effects should be less pronounced than in standing waters due to better water mixing and better oxygenation.

### The freshwater pearl mussel

Freshwater pearl mussel, *Margaritifera margaritifera* (Annex II species of the Habitats Directive) is a rare long-lived bivalve species inhabiting oligotrophic riverbeds. It has an affinity for clean gravel and sandy sediment. Populations are declining sharply across its range and the species is listed in the Red Data Book as endangered. Climate change will result in temporal phenomena that are known to be deleterious to the species (Hastie *et al.*, 2003). River gravels which become heavily silted contain insufficient oxygen to support the young larvae and recruitment to the adult population has seriously declined across their distribution. Further habitat siltation, as well as increased nutrient input, can be detrimental to its already decreasing populations in Ireland. A secondary effects of climate change affecting pearl mussels is a potential decline in salmonid fish density. *M. Margaritifera* recruitment success depends on juvenile salmon and trout population as its parasitic larvae attach themselves to their gills (Moorkens, 1996, Lee *et al.*, 2003). Increased flooding and drought episodes in rivers has already contributed to declines in some rivers holding the pearl mussel and this is likely to be exacerbated over the next 50 years (Hastie *et al.*, 2003).

Elevated temperature will have a direct and immediate effect on freshwater life. Scientists at Cardiff University predict that the number of stream macroinvertebrates may fall by up to 21% in spring for every 1°C rise (BBC, 2007). Rivers and streams, especially the shallow ones, will be more exposed to desiccation during low flow periods. The invertebrate life which sustains trout and other stream fishes will be significantly affected if the river bed becomes dry (Ormerod & Watkinson, 2000).

Increased growth of various species of aquatic plants (both native and invasive) in Irish waterways has been noted to cause a management problem by impacting or blocking the navigation channels (Eamonn Horgan, Waterways Ireland, pers. comm). While this is a result of several factors, overall increases in both water and ambient air temperature have certainly played an important part and the problem is expected to escalate. There has been a steep decline in the numbers of juvenile eels entering Ireland's rivers in the last two decades. Oceanic changes have been identified as one of many possible reasons, along with pollution and overfishing (Castonguay *et al.*, 1994; Knights, 2003).

These impacts will have an influence on human life in a variety of ways. The decrease in freshwater food supply and habitat available for spawning has had a negative impact on already struggling salmon stocks. Additional pressure concerns a possible lack of water to feed the canals during low flow periods leading to loss of amenities, such as navigation.

### Wetlands

Wetlands are characterised by permanent or temporary inundation and plants and animals that have adapted to life in saturated conditions. Changes in climatic conditions that affect water availability will significantly influence the nature and function of specific wetlands, and will impact on the plant and animal species within them.

The distribution and functioning of wetlands in Ireland will be significantly impacted by a rise in temperatures and altered precipitation patterns, including more frequent droughts (Bergkamp *et al.*, 1999). There is a fear that blanket bogs may dry out as a consequence of climate change. It is likely that many wetland ecosystems will experience water stress with peatlands being amongst the most vulnerable of Irish ecosystems (Jones *et al.*, 2006). Wetlands cover 16% of the surface of Ireland and peat-bogs represent 95% of this total (EEA, 2004). A recent study showed that areas of optimal climatic conditions for peatlands would be significantly reduced in future and eliminated towards the end of this century as a result of climate change (Jones *et al.*, 2006). Additional pressure on the freshwater wetlands in coastal areas is expected due to predicted seawater inundation as a result of elevated sea water levels and increased storm surge. This could result in their conversion into saltmarshes in affected areas. With the wetland habitat shrinking, some of Ireland's rare protected species, including Annex II listed snails *Vertigo geyeri* and *V. moulinsiana*, as well as the rare *V. lilljeborgi*, could be threatened with extinction (Evelyn Moorkens, pers. comm.).

Wetlands are estimated to occupy 0.64 % of the planet yet they account for 15% of the productive output of ecosystem services globally such as waste treatment or water regulation (Costanza *et al.*, 1997). Floodplains for example, store water when rivers over-top their banks, reducing flood risk downstream, reducing the need for costly dams and retention walls and at the same time providing an important habitat for a variety of wildlife, including birds. Wetlands feature a large number of ecological niches and harbour a significant percentage of the world's biological diversity. At the same time, wetlands and peatlands represent important carbon stores and contribute significantly to the global carbon cycle reducing the accumulation of CO<sub>2</sub> in the atmosphere (Patterson, 1999).

### 5.3.3 Coastal areas

Recent findings and predictions strongly suggest that global climate change has already had an effect on marine biodiversity and ecosystem functioning (Hughes, 2000, Walther *et al.*, 2002, Kendall *et al.*, 2004). Effects of climate change on the marine environment include an increase in water temperatures, sea level rise, changes to ocean currents, increased storminess, changes to salinity and ocean acidification. The residual effect will depend on the habitat characteristics of the different coastal systems. For the purpose of this study, these are divided into: intertidal zone, bays and shallow inlets, and transitional waters. An additional section is dedicated to marine megafauna (large, usually widely dispersed or migratory animals, such as whales, dolphins, seals, or turtles) as they are not confined to any of the aforementioned areas.

#### *Intertidal habitats*

An extension of vertical zones (i.e. sublittoral zone, low-, mid-, and high-shore, splash zone) landwards, along with associated species, will occur as a result of sea level rise (Hiscock *et al.*, 2004). Invertebrates are likely to respond by relocating to a more suitable habitat when conditions become unfavourable. However, vertical relocation of species and their communities is only possible where space is not a limiting factor. Land adjacent to both inland and coastal waterbodies tends to be valued by humans and as a result more developed than sites inland. Without alternative space to migrate, organisms affected by sea level rise might be reduced in extent along the developed stretches of coastline. The impacts of air temperature extremes that are buffered in permanently submerged coastal environments can be detrimental to many organisms of the intertidal zone. The direct effects of increased atmospheric precipitation on shore species will alter the salinity balance. Further effects will depend on the nature of the substratum (hard or soft) and are discussed below.

#### *Rocky shores*

More frequent and severe storms will increase the physical stress on rocky shores, while higher temperatures will increase desiccation. Furoid algae (brown algae) are characteristic of northern shores (Ballantine, 1961) and are common around the Irish coast. As sea and air temperatures increase, it is likely that furoid cover on moderately exposed shores will decline (Kendall *et al.*, 2004). This might be exacerbated at more exposed shores by the effects of increases in storminess. Brown algae that are common around the Irish coast and susceptible to increased wave action include *Fucus serratus*, *Ascophyllum nodosum*, *Fucus vesiculosus*, *Fucus spiralis* and *Pelvetia canaliculata*; these species will be adversely affected should storm surge magnitude or frequency increase (Emblow *et al.*, 2004).

Canopy-forming algae are an important shelter for a number of invertebrate species, including small crustaceans, sea anemones, hydroids, bryozoans, and polychaete worms. This community will be affected by the decline of brown algae. Increased solar radiation during low tide exposure causes desiccation stress. Overheating in upper shore pools and on open rock in 1976, when the summer temperatures were particularly hot, resulted in mortality of the cold water limpet, *Patella vulgata*, on the Scottish coast (Bowman, 1978).

As a result of increased temperatures, intertidal green algae (e.g. *Enteromorpha* spp. and *Blidingia* spp.) are likely to occur for shorter periods and be absent during most of the summer as is the case in more southerly latitudes than Ireland (Hiscock *et al.*, 2004). Southern species on the other hand, will find more favourable survival conditions under milder winter temperatures. Certain rock pool fishes, such as blennies and gobies, may remain on the shore for a longer period of the year instead of retreating to deeper waters for winter. The snakelocks anemone, *Anemonia viridis*, is expected to survive better and higher up the shore than before (Hiscock *et al.*, 2004).

#### **The barnacles**

One of the most apparent biotic responses to climate change was observed in barnacle species within intertidal rocky shore environment. Changes in relative abundance of Boreo-arctic *Semibalanus balanoides* and two warm-water species of *Chthamalus* were very closely linked to climate fluctuation observed over the second part of the twentieth century (Hawkins *et al.*, 2003).

### *Sediment (mud, sand and gravel) shores*

The population dynamics of common intertidal burrowing bivalves, such as cockles (*Cerastoderma edule*), sandgapers (*Mya arenaria*), and Baltic tellins (*Tellina tenuis*), are strongly related to temperature fluctuations (Philippart *et al.*, 2003) and changes in population dynamics of some of these invertebrates have been linked to temperature fluctuations in an Irish context in the past (Wilson, 1990; 1993). These and many other sediment-dwelling invertebrates of intertidal flats are a very important food source for birds and population fluctuations may result in food shortages. Some of the burrowing bivalves (e.g. cockles) are commercially exploited for human consumption and this industry will be affected if sediment fauna becomes exposed to increased desiccation stress.

Sediment characteristics, including grain size and organic matter content, are one of the basic determinants of species distribution. Sediment shores are highly susceptible to erosion, which is expected to increase as a result of storm surges. Sand dunes play an important role in the sediment interchange between land and the sea. The increasing relocation of this sand reservoir as a result of increased penetration by sea will result in large-scale shifts of sediment characteristics. This will lead to relocation of shore habitats and more fluctuating conditions for burrowing animals, although the overall net effect is difficult to predict (see Chapter 4, section 4.3.4).

### *Bays and shallow inlets*

Semi-enclosed and sheltered locations with less dilution from water currents may experience locally increased surface water warming. As a result, these areas might become more susceptible to concentrated algal blooms, with increased occurrences of biotoxins (toxic algal blooms) (Hiscock *et al.*, 2004). In areas with poor vertical mixing of the water column, deeper waters may become isolated through thermal stratification during summer and consequently become more susceptible to de-oxygenation. Such incidents were observed in Sullom Voe (Pearson & Eleftheriou, 1981) and Loch Obisary (Mitchell *et al.*, 1980) in Scotland and are likely to become more frequent (Hiscock *et al.*, 2004).

Subtidal algae of conservation interest around Ireland that are sensitive to wave exposure include sea grasses (*Zostera* spp.). *Zostera* grows in sediments in sheltered locations creating extensive meadows. They offer shelter to number of species and are considered biodiversity hotspots. If populations are found in moderately strong currents, they tend to become patchy as a result of the sediment erosion and vulnerable to storm damage. Young populations may be highly sensitive to eroding wave action since they have not developed a robust rhizome system (Emblow *et al.*, 2004). Sea grass habitats could also be adversely affected by increase storminess.

### *Transitional waters (estuaries, lagoons and salt marshes)*

Estuaries are regarded as being among the most productive ecosystems on Earth (Costanza *et al.*, 1997) and they are rich feeding grounds for birds, as evidenced by the high number of estuaries in Ireland designated as SPAs. They are also important spawning and nursing grounds for a number of open water fish species (Emblow *et al.*, 2004).

Freshwater runoff carried into estuaries by watercourses altered by changed precipitation patterns may lead to changes in salinity gradients. Organisms react to salinity change much the same way as they do to pollution (Wilson, 1994) and very few organisms can tolerate a wide range of salinity. This salinity effect can lead to estuarine squeeze, where stable biotic conditions will be confined to a narrower zone than at present (James Wilson, TCD, pers. comm.).

Higher rainfall may also lead to higher sediment and contaminant loads entering estuaries (Emblow *et al.*, 2004). The combined effects of variable salinity and increased contaminants may lead to even more pronounced shifts in living conditions. This will favour organisms with short life spans and fast reproductive rates characteristic of impacted areas, over long-lived larger fauna typical of stable conditions (Clarke & Warwick, 2001). Increased river discharge during high rainfall periods is likely to deposit higher levels of nutrients into the estuaries increasing the potential for blooms of algae that, in turn, deplete the water of oxygen and impose further stress on fauna.

If water quality in river mouths and estuarine systems deteriorates so as to form a barrier to the migratory passage of anadromous (those which breed in freshwater and migrate to seawater to feed) and catadromous species (those which breed in seawater and migrate to freshwater), populations of migratory fish species will be adversely impacted (Emblow *et al.*, 2004). These include a few Annex II listed species of the Habitat Directive: Atlantic salmon (*Salmo salar*), sea lamprey (*Petromyzon marinus*), river lamprey (*Lamprolaima fluviatilis*), twaite shad (*Alosa fallax*) and allis shad (*Alosa alosa*).

Many coastal lagoons require periodic inundation by seawater to maintain their brackish salinity state. Such lagoon systems are likely

to be subjected to significant changes in species composition if storm events cause breaches to coastal barriers allowing larger amounts of seawater into the system, unbalancing the salinity regime (Emblow *et al.*, 2004). Over the last 100 years there was no evidence of any significant loss of coastal lagoon habitat range. However, their structure, function and future prospects are regarded as unfavourable (NPWS, 2008b). The lagoon snail species *Hydrobia ventrosa* and *Hydrobia acuta s. neglecta* are in danger of extinction in Ireland due to increased vulnerability of lagoons, with one of the areas of vulnerability being excessive flooding or storm damage (Evelyn Moorkens, pers. comm.).

Salt marshes are an important element of estuarine food chains, providing an important food source for juvenile crustaceans and fish, while also providing an important habitat for birds. Salt marsh vegetation acts as a cushion between the seafront and the land by slowing down the current velocity and trapping the sediment. The ability of salt marshes to trap sediment constitutes its vital characteristics of adaptability to the sea level change by sediment accumulation. In such a way salt marsh acts as a buffer, limiting the extent of flooding events while at the same time providing a valuable habitat for wildlife (Keller & Causey 2005). Salt marshes can be affected by a periodically increased freshwater input (from the land side) and by increased erosion on the sea side. As discussed in Chapter 4, if subjected to low sediment availability, salt marshes can suffer as a result of sea level change. It appears that landward migration will be crucial for their survival. In locations where there is no alternative space for salt marsh communities, large scale species exclusion may occur. These will range from fauna and flora that salt marshes directly harbour to a wide range of estuarine fauna species that feed on their productive output, including invertebrates, fish and birds.

### Marine megafauna

Numerous species of marine megafauna have been recorded in Irish waters including some 24 species of cetacean (whales and dolphins) (IWDG, 2008), two seal species (grey and common seals) and two turtle species (leatherbacks and loggerheads) (Irish Sea Leatherback Turtle Project, 2008).

A number of cetacean species are resident in Irish coastal and offshore waters, while other species appear only seasonally as part of their migration. The effects of climate change on these species may include alterations to food resources, especially to shoaling bait-fish such as sprat (*Sprattus sprattus*) and herring (*Clupea harengus*) on which many species, including fin whales (the second largest animal in the world after the blue whale) depend. Greater productivity of plankton and schooling fish, especially off the south and southwest coast of Ireland could contribute to an increase in occurrence of species such as baleen whales or basking sharks (*Cetorhinus maximus*) (Simon Berrow, IWDG, pers. comm.). Some species of cetacean are found only in cool water areas, while others are associated with only tropical waters (Learmonth *et al.*, 2006). In light of this, an increase in water temperature around the Irish coast may result in the exclusion of cool water species, while warm water species may expand their range or abundance.

The northerly distribution of the critically endangered leatherback sea turtle (*Dermochelys coriacea*) was found to be limited by the position of the 15°C isotherm, but its mean position during the summer months has moved north by 330km in the North Atlantic in the last 17 years (McMahon & Hays, 2006). Leatherback turtle distribution is predicted to extend further north as warmer waters extend into higher latitudes. Increasing water temperature is also likely to have a secondary effect on the migratory turtles and sunfish (*Mola mola*) via changes in the distribution of jellyfish in Irish waters, as they feed exclusively on jellyfish (Houghton *et al.*, 2006). In November 2007 an enormous swarm of the oceanic jellyfish *Pelagia noctiluca*, normally associated with the Mediterranean, occurred off the coast of Northern Ireland. The swarm extended for about 10 square miles and had economic consequences by killing some 100,000 farmed salmon enclosed in cages, at a cost of £1 million (Reuters, 2007).

Sea level rise is also a significant factor for some species. Rising water levels will have an impact on the breeding and nursery haul-out sites of grey (*Halichoerus grypus*) and common (*Phoca vitulina*) seals (Learmonth *et al.*, 2006), in turn affecting the reproductive success of these species around the Irish coast.

As with so many other areas of aquatic ecology, the likely impacts of climate change on marine mammals and other marine megafauna are uncertain, with many large gaps in our knowledge. A better understanding of the changes that will result from climate changes and more research into many areas of megafauna biology and ecology will be required to provide more concrete answers to these questions. Changes in the NAD that might occur as a result of climate change could be accountable for further changes in distribution of open ocean migrants and drifters. Even though changes in oceanic currents due to climate change are uncertain, there is some indication that they are already taking place (Häkkinen & Rhines, 2004).



### 5.3.4 Impacts on birds

#### Temperature shift

Spring temperatures in temperate regions have increased over the past 20 years, and many organisms have responded to this increase by advancing the time of their reproduction and accelerating their growth. For long-distance migrants, climate change may advance the timing of their breeding, but the timing of some species' spring migration relies on their internal biological rhythms that are a genetic adaptation and are not as easily affected by climate change (Both & Visser, 2001). Therefore, the spring migration of these species will not advance from year to year, even though they would need to arrive earlier to breed at the appropriate time. For example, the pied flycatcher (*Ficedula hypoleuca*) has advanced its nesting date over the past 20 years (Both & Visser, 2001). However, the adjustment to climate change is constrained by its spring arrival date, which has remained unchanged. In such a way, some of the numerous long-distance migrants arriving in Ireland will be impacted, because their migration timing is unaffected by climate change, while the conditions in breeding and wintering areas are changing. This might prevent adequate adaptation to food availability for offspring. These species will respond by shifting their ranges and Ireland will experience some degree of community re-assembly. On the other hand, some species are able to adapt their breeding activities. Both processes, community re-assembly and adaptation of breeding activity occur simultaneously. Under current climate change forecasts, changes in the proportion of migratory species will be modest and the communities of migratory birds in Europe are projected to be altered through adaptation of migratory activity rather than through exchange of species (Schaefer *et al.*, 2008).

Overwintering waders appear to be good indicators of the effects of climate change. A number of these species have moved in Britain at least in part, either eastwards along the winter isotherms or northwards. These changes in distribution broadly coincide with a distributional shift towards the species' respective breeding grounds and are correlated with the local winter weather over the period: increasingly less extreme temperatures and changes in mean rainfall, mean wind speed, and wind-chill (Rehfishch *et al.*, 2004).

In Ireland a number of organisms live close to their geographical limits of distribution. Some of these species might be expected to extend their range as climatic restraints are relaxed. Bird species associated with cool summers or low winter temperatures, such as the common eider (*Somateria mollissima*) will move northwards (Kendall *et al.*, 2004).

#### Food web interactions

Climate change will cause distribution changes in many of the common invertebrate species that live on rocky and sediment shores. Where these changes are significant, they will impact on the distribution of birds that depend on invertebrates as a food source.

There is a concern that as the climate warms, the abundance and productivity of brown algae will decrease and this in turn will adversely affect the associated invertebrate community living on or under their fronds. This is likely to have significant effects for waders as it would represent a loss of potentially rich feeding grounds for species such as the turnstone (*Arenaria interpres*) that feed on small invertebrates living on or beneath the seaweed (Kendall *et al.*, 2004).

Seabird population changes are occurring in the North Sea as a result of food web alterations and these include starvation and consequently a reduction in reproductive success (Kitaysky *et al.*, 2005; Dybas, 2006). These changes have been attributed, at least in part, to the temperature shifts. For instance, the sand eel, a species which seabirds prey upon, are decreasing due to both, the northward movement of their food (plankton) and to over-fishing, leaving very little alternative food for birds (Dybas, 2006). It is highly likely that the breeding populations of terns, gulls, and cliff nesting species (kittiwakes, guillemots, and fulmars) will respond to such changes, if they have not done so already.

#### Habitat loss and dispersal possibilities

Estuaries and salt marshes play a vital role in sustaining many bird species and any changes to these areas are likely to affect their populations, through the loss of food, nesting, and roosting grounds. For example the abundance and density of the common red-shank (*Tringa totanus*) were significantly affected by the reduction of their nesting habitat through grazing (Norris *et al.*, 1998). Wetland alterations resulting from climate change will have a similar, if not more dramatic, effect on their abundance. They will be stimulated to follow the habitat succession provided that there will be an alternative space available for the habitat and species to move to. Even then, range changes can be delayed because it takes time for suitable habitat conditions to develop elsewhere (Huntley *et al.*, 2007).

### 5.3.5 Conclusion

Climate change can influence biological communities through a combination of the effects mentioned above. The residual impact is a very complex one as climate change affects organisms along many ecological axes simultaneously. It includes secondary effects that result from altered species interactions (Table 5.2). Because of that, predictive models are very difficult to construct and, indeed, very few are available in published literature (e.g. Hiscock *et al.*, 2004). Instead, virtually all cause-effect relationships to date have been based on empirical observation. As they are a cumulative effect of the multiple effects of climate change, as well as other natural and man-made pressures, these apparent impacts can seldom be attributed unequivocally to climate change, and long-term time-series data are nearly always a prerequisite.

Some good data time-series are available for marine ecosystems and some of them can be applied to Irish coastal waters, including over 80 years of monitoring data from Plymouth Marine Laboratory (Southward *et al.*, 1995). However, this type of data is virtually non-existent for inland waterways of Ireland. In the absence of sufficient evidence there remains a degree of uncertainty about the biological effects of climate change on freshwater habitats. Nevertheless, their coincidence with recent trends in climatic phenomena and changes observed in marine environments suggest that many of them are indeed related to global warming and are likely to continue.

Table 5.2. Summary of impacts on natural heritage in Ireland

	Temperature and desiccation	Precipitation and altered hydrological regime	Sea level rise and storm surges	Adaptation
<b>GENERAL</b>	<ul style="list-style-type: none"> <li>- Biogeographical shift in species composition</li> <li>- Greater settlement success and spread of alien species</li> </ul>	Not applicable (all impacts system-specific)	Not applicable (all impacts system-specific)	<ul style="list-style-type: none"> <li>- Reduce anthropogenic pressures to ensure a balanced and resilient receiving species community and minimise the risk of bio-invasion</li> <li>- Control vectors of species introduction (boat wash procedures, handling ballast waters, etc.)</li> </ul>
<b>INLAND WATERWAYS</b>				
<b>Standing waters</b>	<ul style="list-style-type: none"> <li>- Excess algae and plant growth</li> <li>- More frequent eutrophication</li> <li>- Reduction in abundance and/or distribution of species with low heat tolerance</li> <li>- Decline in salmonid fish and increase of coarse fish</li> </ul>	<ul style="list-style-type: none"> <li>- Decreased overall productivity and biodiversity through greater air exposure of the shallows</li> <li>- Decline in long lived species and increase in fast re-colonizers along the water margins</li> <li>- Increased nutrient load</li> <li>- Altered littoral and shore habitat distribution through variable immersion regime</li> </ul>	<ul style="list-style-type: none"> <li>- Saline inundation in coastal areas can inflict a wide-scale habitat loss</li> </ul>	<ul style="list-style-type: none"> <li>- Bring to a good ecological status to maximize resilience</li> <li>- Create functional ecological network of sites to allow species succession</li> </ul>
<b>Running waters</b>	<ul style="list-style-type: none"> <li>- Reduction in abundance and/or distribution of species with low heat tolerance</li> <li>- Excess algae and plant growth</li> <li>- More frequent eutrophication</li> <li>- Decline in salmonid fish</li> </ul>	<ul style="list-style-type: none"> <li>- Decreased overall productivity and biodiversity through greater air exposure of the shallows</li> <li>- Decline in long lived species and increase in fast re-colonizers along the water margins</li> <li>- Altered benthic habitat distribution</li> <li>- Marginal habitats threatened by erosion</li> <li>- Increased nutrient and sediment load</li> <li>- Impact on species dependent on water clarity</li> <li>- Smothering of benthic species and habitats (e.g. gravel beds)</li> </ul>	<ul style="list-style-type: none"> <li>- Flora and fauna in lower reaches replaced by estuarine species</li> </ul>	<ul style="list-style-type: none"> <li>- Bring to a good ecological status to maximize resilience</li> <li>- Create functional ecological network of sites to allow species succession</li> <li>- Rehabilitation of natural channel morphology (meanders, riffle areas, marginal vegetation)</li> <li>- Revitalise floodplains to reduce flow extremes</li> </ul>
<b>Freshwater wetlands</b>	<ul style="list-style-type: none"> <li>- Decrease of insects with an aquatic larvae</li> <li>- May shrink significantly; blanket bogs particularly at risk and may possibly disappear</li> </ul>	<ul style="list-style-type: none"> <li>- Periodic or permanent desiccation will cause species succession and wetland loss</li> <li>- Decrease of insects with an aquatic larvae</li> </ul>	<ul style="list-style-type: none"> <li>- Saline inundation in coastal areas can inflict a wide-scale habitat loss</li> </ul>	<ul style="list-style-type: none"> <li>- Rehabilitation of natural hydrology in wetland areas (close arterial drainage)</li> </ul>

	Temperature and desiccation	Precipitation and altered hydrological regime	Sea level rise and storm surges	Adaptation
<b>COASTAL AREAS</b>				
<b>Intertidal habitats</b>	<ul style="list-style-type: none"> <li>- Excess algae and plant growth</li> <li>- More frequent eutrophication</li> <li>- Decline of brown algae and associated fauna</li> <li>- Green algae likely to occur for shorter periods</li> </ul>	<ul style="list-style-type: none"> <li>- More variable osmotic pressure on organisms as a result of varying salinity</li> </ul>	<ul style="list-style-type: none"> <li>- Loss of coastal habitats</li> <li>- Extension of intertidal zones landwards</li> <li>- Intertidal area shrink significantly in developed areas</li> <li>- Increased physical stress on macrophyte algae through wave action</li> <li>- Habitat alteration through erosion and re-deposition of sediments</li> </ul>	<ul style="list-style-type: none"> <li>- Permeable landscape and managed retreat to allow habitat shift</li> <li>- Bring to a good ecological status to maximize resilience</li> </ul>
<b>Bays and shallow inlets</b>	<ul style="list-style-type: none"> <li>- Reduction in abundance and/or distribution of species with low heat tolerance</li> <li>- Excess algae growth and increased occurrence of biotoxins</li> <li>- More frequent eutrophication</li> </ul>	<ul style="list-style-type: none"> <li>- More variable osmotic pressure on organisms as a result of varying salinity</li> </ul>	<ul style="list-style-type: none"> <li>- Increased physical stress through wave action</li> <li>- Impact on seagrass communities</li> </ul>	<ul style="list-style-type: none"> <li>- Reduce anthropogenic nutrient input where applicable</li> </ul>
<b>Transitional waters</b>	<ul style="list-style-type: none"> <li>- Excess algae and plant growth</li> <li>- More frequent eutrophication</li> <li>- Biogeographical shift in species composition</li> </ul>	<ul style="list-style-type: none"> <li>- Increased nutrient load</li> <li>- Fluctuation in water quality with more extremes in water turbidity and nutrient status</li> <li>- More frequent eutrophication</li> <li>- Periodical stress to organisms and barrier to migratory passage of fish</li> <li>- Altered salinity balance in coastal lagoons</li> </ul>	<ul style="list-style-type: none"> <li>- Change in salinity gradients</li> <li>- Landward shift of estuarine species and habitats</li> <li>- Estuarine 'squeeze' in developed areas</li> <li>- Reduced feeding opportunities for birds</li> </ul>	<ul style="list-style-type: none"> <li>- Reduce other pressures on the systems to maximize resilience at a catchment level (River Basin Management Plan)</li> <li>- Permeable landscape and managed retreat to allow habitat shift and avoid 'estuarine squeeze'</li> </ul>
<b>Marine megafauna</b>	<ul style="list-style-type: none"> <li>- Altered interactions on the base of the food chain might change migratory routes</li> </ul>	<ul style="list-style-type: none"> <li>- Not determined</li> </ul>	<ul style="list-style-type: none"> <li>- Reduction of breeding and nursery haul-out sites of seals</li> </ul>	<ul style="list-style-type: none"> <li>- Alternative haul-out sites for seals</li> <li>- Marine protected areas to secure food for cetaceans</li> <li>- Reduce fishing effort on shoaling bait-fish</li> </ul>
<b>IMPACTS ON BIRDS</b>				
	<ul style="list-style-type: none"> <li>- Species shift</li> <li>- Possible mismatch between the time of breeding and dynamic of food items</li> <li>- Reduction of wetland habitat</li> </ul>	<ul style="list-style-type: none"> <li>- Reduction of wetland habitat</li> </ul>	<ul style="list-style-type: none"> <li>- More variable feeding opportunities at sea due to more frequent storms</li> <li>- Poorer feeding opportunity in estuaries and intertidal areas</li> </ul>	<ul style="list-style-type: none"> <li>- Rehabilitation of natural hydrology in wetland areas (close arterial drainage)</li> <li>- Create functional ecological network of sites to allow feeding and nesting alternatives</li> <li>- Permeable landscape and managed retreat to allow intertidal and estuarine habitat shift</li> </ul>

## 5.4 Policy response and adaptation

The European Council meeting of December 2004 recommended that a temperature ceiling of no more than 2°C above pre-industrial levels was necessary if significant adverse impacts were to be avoided. There are a number of uncertainties surrounding the achievability of this target, but should there even be a temperature rise of less than 2°C, significant climate change impacts on natural heritage of inland waterways and coastal waters are expected to occur in Ireland during the coming decades (Table 5.2). Urgent action is required and with suitable adaptation measures in place some effects of these climate change impacts can be minimized or avoided. Early action will be more cost-effective and sustainable than delayed reaction.

The Intergovernmental Panel on Climate Change defines adaptation as 'adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities' (IPCC, 2007). Despite growing awareness about the climate change amongst stakeholders, the adaptation activities concerning biological effects are generally lacking. For example Ireland's National Climate Change Strategy 2007-2012 makes no mention of adaptations pertaining to natural systems.

Serious and immediate action leading towards controlling the emission of greenhouse gasses (GHG) is the only way of preserving the environment as we know it and thus sustain human life in the long term. Any other measure may yield only ameliorating effects and these actions may be considered within two main categories:

- Providing alternative space to which species can move
- Reducing stress caused by other pressures

In order for the above to be effectively implemented there is a need for good quality information on the biological effects of climate change. This information needs to be available to all stakeholders and be followed up with appropriate management practices. Those practices which are applicable to the natural heritage of inland waterways and coastal waters are discussed below.

### 5.4.1 Alternative space

- Managed retreat and sacrificial land
- Functional ecological network of sites (Natura 2000)
- Permeable landscape

The fact that there is already evidence that climate change has resulted in a change in the distribution of habitats and species in Ireland and other European countries means it is necessary to consider action to create alternative space for species and habitats put under pressure by effects such as rising sea levels.

Temporary ameliorative measures, such as hard defence walls, usually ignore the need to preserve the environment by failing to recognise not only the importance of natural heritage but also its significance for our well-being. Managed retreat (or managed realignment), where the water is allowed to penetrate landwards in certain areas, is another response to raising sea levels and increased coastal flooding that should be considered. Managed retreat offers a way of meeting the challenge of inevitable change, rather than waiting until there is an emergency. It protects both wildlife and the people who live and/or work in coastal areas. It works with nature rather than against it and can provide alternative space for species to move to, as well as allowing for the landward movement of certain intertidal habitats.

The concept of a managed retreat and sacrificial land is already being applied in the UK and some other European countries. Some of these models could be applied to the Irish situation (e.g. Rupp & Nicholls, 2002; Leggett *et al.*, 2004). A dramatic example of this approach is that taken at Wallasea Island, Essex, where 115 hectares of land was flooded by deliberately breaching the sea wall protecting the area from the sea. The aim of this project was to create a wetland to provide habitat for waterbirds and to provide flood defence to the surrounding area (DEFRA, 2006). While the instigation of this project was as a result of an EU Court of Justice ruling that the UK must provide replacement areas of wetland for that left out of an SPA to allow a port development, the approach is one that deserves further consideration in an Irish context.

The provision of sufficient areas of wetland, estuaries, mudflats and sandflats, is of critical importance to waterfowl. 'Natura 2000' is intended to provide a network of interrelated sites that will allow the continued survival of wild species of fauna and flora. A

large-scale functioning network of such sites is of particular relevance to birds, particularly those that make large scale migrations such as Brent geese (*Branta bernicla*). These species depend on stopover areas to feed in the course of their migrations, thus requiring a network of suitable sites along the migration route. Even at a smaller scale than that of migratory birds, species need sufficient alternative space if they are to adapt to changes brought about by climate change by moving to a more suitable location. The importance of these areas and the need to implement appropriate management for the protection of birds is highlighted by Huntley *et al.* (2007).

It is essential that we act consistently to provide a permeable landscape where species have maximum adaptability and refuge chances. Such a strategy requires the availability of stepping stone habitats on a scale from very small (e.g. revival of strings of ponds) to large (e.g. restoration of floodplains). The extent of biodiversity loss will depend on the availability of alternative space and the presence of dispersal barriers. Habitat fragmentation needs to be offset by landscape permeability if we are to counteract the biological effects of climate change.

#### 5.4.2 Influence of other stressors on living systems

- Implementation of the EU Water Framework Directive
- Rehabilitation of waterways
- Dynamic approach to conservation

While climate change is likely to cause considerable negative impacts on the natural heritage of Ireland's coast and inland waterways, these impacts will be exacerbated by existing anthropogenic pressures such as nutrient enrichment, arterial drainage of wetlands or pollution, to name but a few. Work must continue to address the sources of stress on the natural aquatic environment, in particular through the EU Water Framework Directive which aims to manage catchments with the aid of ecological, chemical and morphological criteria. Measures to limit the discharge of nutrients, such as phosphorus and nitrogen, into waterbodies have been implemented in Ireland (Phosphorus regulations, 1998 and Nitrate regulations 2006). Actions such as these are vital to protect aquatic systems and rehabilitate sites, thus increasing their capacity to deal with the impacts of climate change.

Wetland ecosystems provide important water regulation services, both in terms of water quality and quantity. They also provide opportunities for amenity and recreation, including activities such as birdwatching, angling, and sport hunting. Given that tourism is one of our leading industries, the economic value of these can be considerable. Maintaining wetlands and capitalising on these values can be a valuable alternative to more disruptive uses and degradation of these ecosystems. Increasing the water retention capacity of waterways and catchments by means of active floodplains and wetlands is a way of providing a buffer mechanism to counteract impacts induced by higher flow variability. The rehabilitation of waterways that have been impacted by historical arterial drainage is an important element to this action, which would include reverting rivers to their natural morphological characteristics, with diverse habitats and robust bankside vegetation (Rosgen, 1994). There are a number of initiatives actively involved in bogs restoration projects, such the one jointly funded by EU DG-Environment and Coillte Teoranta (<http://www.irishbogrestorationproject.ie>). This sort of effort should be encouraged and continued.

Most conservation policy tools are based on *status quo* assumptions and they tend to focus on preserving current situation or past conditions known to be favourable. Potentially suitable climate conditions for species and habitats will shift with the climate change; therefore the notion of a dynamic approach to nature conservation should be developed and factored into national policy. Rigorous guarding of fixed geographical boundaries of protected areas might prove to be insufficient to maintain healthy populations of species and network of habitats. A dynamic approach to conservation is currently lacking in most nation-wide policies.

Climate change has wide implications for active conservation practises, such as reintroduction of locally extinct species or exclusion of the ones deemed undesirable (for example, the tree canopy is commonly cleared to maintain heathland habitats).

#### 5.4.3 Research and monitoring

- Research on response of organisms and their communities to climate change
- Long term data (time-series)
- Data integration and dissemination
- Monitoring of changes resulting from climate



There are a substantial amount of research platforms that are focused on the mechanisms and physical impacts of climate change in Ireland. Nevertheless, these are generally lacking in the area of natural heritage. This deficiency should be targeted by researchers and funding bodies.

Climate change will result in a change in the physical and biological environment for many aquatic organisms. However, to what extent these are able to change their distribution, behaviour, physical or biochemical (phenotypic) characteristics or how populations will respond genetically in order to adapt is not known and will require research in order for us to gain a fuller appreciation of the issue. This work should involve the development of the appropriate biophysical models. There are numerous gaps in our knowledge and understanding of the effects of climate change on coastal habitats and inland waterways, and extensive research and monitoring will be required to address these gaps and begin to understand the complexities of the problem.

According to most Irish experts consulted in the course of this study, insufficient observation has been carried out for them to state unequivocally that the effects of climate change have resulted in physical and biological changes in the environment. The absence of long-term data means that factors such as natural cycles can not be ruled out in our search for the causes of environmental change. There is a lack of long-term data necessary to allow the separation of the impacts of climate change from other factors, including natural cycles. One example of this would be the case of the little egret whose arrival in Ireland is commonly given as an example of climate change, but which has been undergoing a general expansion (Colmán Ó Críodáin, NPWS, pers. comm.). The majority of evidence is in the form of anecdotal information rather than scientifically robust data and this is reflected in the many references to personal communications as information sources in this chapter.

The research infrastructure for data integration and dissemination in Ireland is deficient. Such an infrastructure is necessary to model future trends and impacts associated with climate change, including effects on ecological processes and food webs and to implement a long-term monitoring programme. In the Irish context, this work should be carried out at an all-island level and appropriate coordination and calibration with international research should be initiated. This would include Ireland being better represented at various international fora and the establishment of an Irish forum of climate change impacts similar to the UK Marine Climate Change Impacts Partnership. The National Biodiversity Data Centre was in a start-up phase at the time of writing, but could be developed into a fully functional data exchange platform to allow data standardisation, integration, and dissemination in order to allow a better coordination and accumulation of research effort.

The integration of past and newly acquired data could form the basis for baseline and monitoring studies. This can be achieved for coastal waters by the national Marine Climate Change (MCC) research programme launched by the Marine Institute in December 2007. The program will examine changes in abundance and geographic distribution of phytoplankton, zooplankton, and fish in relation to the variations of the ocean's physical conditions. Similar initiatives are urgently needed within freshwater research. The monitoring of changes resulting from climate change could be incorporated into the requirements of the existing legislative framework such as the Habitats Directive and the Water Framework Directive. This would include the monitoring of the expansion of the range of southern species or invasive aliens likely to be directly related to the effects of climate change. The Countryside Survey, which is being developed by the National Biodiversity Data Centre, could play an important part by monitoring the changes in spatial extent of habitats with a high resolution (Liam Lysaght, NBDC, pers. comm.).

The SALSEA-Merge initiative is a good example of a multinational integration of research effort. With an extensive sea survey to be carried out during 2008-09 along with genetic studies, the researchers are aiming to advance the understanding of stock specific migration and distribution patterns of Atlantic salmon to help explain its mortality at sea. It brings together 21 organisations from eight countries. Irish involvement includes the Marine Institute and NUI Cork. The total cost of €5.5 million is funded under the European Commission's Seventh Research Framework Programme with significant contributions from partner organisations (NASCO, 2008).

#### 5.4.4 Awareness

- Some people remain unconvinced that climate change will have any significant impact
- The importance of early exposure of children to the topic of climate change
- Direct involvement

There have been some awareness activities recently carried out quite successfully, such as the EPA Climate Change Lecture Series. While these sorts of activities should be encouraged, more emphasis should be placed on the smaller issues behind the bigger pic-

ture (i.e. what climate change means for species and habitats in our locality and how it is going to affect us and our families).

An interesting approach was taken by The Irish American Climate Project by conveying scientifically supported implications of climate change through activities as music, poetry, or leisure events, thus reaching a wider audience than more conventional means could (Sweeney *et al.*, 2008). The possibilities of this sort of hybrid approach could be further explored and crafted to reach certain target groups. The early exposure of children to the topic of climate change should be included in the curriculum. This would form the starting point of changing attitudes towards sustainable resource usage and the emission of GHGs.

By far, the most effective way of raising public awareness appears to be through direct involvement and interactive activities should be prioritised. For example, the InterEST (Intertidal Ecology Skills Training) project developed under a Heritage Council grant and carried out jointly by Marine Dimensions and EcoServe involves field exercises with secondary school students. This project introduced the students to the intricacies of the marine environment, while also drawing their attention to species succession as a result of climate change. These sorts of activities form a good foundation for a general change of attitude toward the environment.

While awareness amongst the general public is vital and is an area that must be targeted, awareness among decision makers, and even environmental professionals, varies. Even at this level some people seem unconvinced that climate change will have any significant impact on species and habitats. This must be addressed rapidly as high-level decisions are necessary for the implementation of policy and for raising public awareness.

There are some awareness campaigns focused on cutting down the CO<sub>2</sub> emissions and physical impacts of climate change in Ireland. However, these are scarce in the area of natural heritage.

#### 5.4.5 Integrated management strategy

- Joined-up thinking and cohesive policies
- Integrating climate change into ecosystem management: River Basin District (RBD) management, and Integrated Coastal Zone Management (ICZM)

The importance of integrated management to deal with the issue of climate change has been highlighted in the course of the consultation carried out for this chapter. Many government agencies are responsible for areas related to climate change and joined-up thinking is a pre-requisite in ensuring that these different agencies, in concert with Non-Governmental Organisations (NGOs), are working towards the same goal. For instance, the catchment-specific impacts of climate change on inland waterways emphasises the need to integrate climate into the River Basin District (RBD) management plans which are currently being prepared under the Water Framework Directive. Conservation strategies have to acknowledge and address the complexity of biodiversity management and, in particular, species migration that has occurred as a result of climate change. Currently, Ireland's National Strategy for Plant Conservation has failed so far to consider the impacts of climate change. The National Biodiversity Plan (NBP), as it currently stands, mentions climate change only in the context of stabilisation of GHG in the atmosphere, but refrains from discussing its implications on conservation measures, which has been identified as one of its deficiencies (NPWS, 2005a). The rapid changes that may be caused by climate change means that sectors such as marine fisheries will need to adopt adaptive approaches based on ecosystem management. These changes had implications for decision-making and there are concerns that the science which informed those decisions might be inappropriate in a changed climatic present. However, considerable advances will need to be made. As noted earlier, Ireland currently lacks an Integrated Coastal Zone Management (ICZM) policy and coastal management projects are carried out on an *ad hoc* basis.

#### 5.4.6 Examples of adaptation methods used outside Ireland

##### General adaptation

The UK Climate Impacts Programme (UKCIP) helps organisations to adapt to climate change effects. Operating since 1997, UKCIP has been addressing various issues, including biodiversity. It is also an umbrella project for a number of past research initiatives, including MarClim, MONARCH, and ACCELERATES.

##### Alternative space

The Environment Agency in the UK has produced the Shoreline Management Plans for the English and Welsh coasts, and estuaries, such as the Humber Estuary. The number of people and the value of property within the floodplain of Humber Estuary mean it

is essential to continue to provide a line of defences around the estuary. However, in some areas it may be sensible to move the defence line to create intertidal habitat to comply with the Habitats Directive and to reduce flood defence maintenance costs. The Environment Agency's flood defence strategy for the Humber has three main features:

- i. hold the line of the existing defences where there is no justification for moving them;
- ii. identify sites where moving the defences will provide flood defence benefits, both directly and indirectly by reducing the effects of sea level rise; and
- iii. support the creation of intertidal habitat to maintain the estuary's conservation status.

### Research

The Environmental Change Network (ECN) is the UK's long-term, integrated environmental monitoring and research programme. It gathers information about the pressures on and responses to environmental change in physical, chemical and biological systems. It is supported by a consortium of fourteen sponsoring organisations and seven research organisations. The ECN's objectives are:

- i. to establish and maintain a selected network of sites within the UK from which to obtain comparable long-term datasets through the monitoring of a range of variables identified as being of major environmental importance;
- ii. to provide for the integration and analysis of these data, so as to identify natural and man-induced environmental changes and improve understanding of the causes of change;
- iii. to distinguish short-term fluctuations from long-term trends, and predict future changes; and
- iv. to provide, for research purposes, a range of representative sites with good instrumentation and reliable environmental information.

PhytoChange (FP7) is a German project funded under the EU Seventh Research Framework Programme (see below). Phytoplankton are responsible for a major part of global primary production. The project will investigate physiological reactions of three important phytoplankton groups (diatoms, coccolithophores, cyanobacteria) to environmental factors which are linked to global climate change.

The Seventh Research Framework Programme (FP7) is the EU platform for identifying priorities and funding research within the member states. Within the 'Environment (including climate change)' programme, funding focuses on the following:

- Predicting climate, ecological, earth and ocean systems changes
- Tools and technologies for monitoring, prevention and mitigation of environmental pressures and risks including to health
- Sustainability of the natural and man-made environment

### Awareness

The United Kingdom Marine Climate Change Impacts Partnership (MCCIP) is a multi-sector platform for building awareness. It brings together scientists, government and its agencies and NGOs to provide co-ordinated advice on climate change impacts on coast and the seas.

Marine Climate Change Impacts Encyclopaedia (SAHFOS) is hosted by the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) and developed in cooperation with research institutes from UK and France. It addresses the possible effects of climate change on marine life and makes the information accessible to the public on-line.

### List of consultees

Alison Donnelly	Environmental Protection Agency (EPA)
Brendan McSherry	Louth County Council
Caroline Cawley	Bord Iascaigh Mhara (BIM)
Cliona O' Brien	Heritage Council (HC)
Colmán Ó Criodáin	National Parks and Wildlife (NPWS)
Conor Nolan	Bord Iascaigh Mhara (BIM)
Cormac McCarthy	Waterways Ireland
Dan Minchin	Lough Derg Science Group
David Kelly	National Parks and Wildlife (NPWS)
Declan Murphy	BirdWatch Ireland

Dermot Bolger	University College Dublin (UCD)
Eamonn Horgan	Waterways Ireland
Elaine O' Riordan	Galway County Council
Elizabeth Sides	National Parks and Wildlife (NPWS)
Eugenie Regan	National Biodiversity Data Centre (NBDC)
Evelyn Moorkens	Evelyn Moorkens and Associates
Gerry Clabby	Fingal County Council
Gráinne O' Brien	Bord Iascaigh Mhara (BIM)
Ian Lawler	Bord Iascaigh Mhara (BIM)
Ian Montgomery	Queen's University, Belfast
James G. Wilson	Trinity College Dublin (TCD)
Jim Casey	Department of Agriculture, Fisheries and Food (DAFF)
John O'Halloran	University College Cork (UCC)
Julian Reynolds	Trinity College Dublin (TCD)
Karen Gaynor	National Parks and Wildlife (NPWS)
Karin Dubsky	Coastwatch Europe
Ken Irvine	Trinity College Dublin (TCD)
Ken Whelan	Marine Institute
Liam Lysaght	National Biodiversity Data Centre (NBDC)s
Loraine Fegan	Environmental Protection Agency (EPA)
Mairead Stack	Dublin City Council
Marie Mannion	Galway County Council
Martina Prendergast	National University of Ireland (NUI) Galway
Matthew Jebb	National Botanic Gardens
Michael Keatinge	Bord Iascaigh Mhara (BIM)
Mike Jones	Trinity College Dublin (TCD)
Niall Hatch	BirdWatch Ireland
Norman Allott	Trinity College Dublin (TCD)
Oliver Tully	Bord Iascaigh Mhara (BIM)
Oonagh Duggan	Heritage Council (HC)
Patricia Comiskey	Bord Iascaigh Mhara (BIM)
Peter Wyse Jackson	National Botanic Gardens
Rick Boelens	Lough Derg Science Group
Robert Rosell	Agri-Food and Bioscience Institute (AFBI)
Robin Edwards	Trinity College Dublin (TCD)
Russel Poole	Marine Institute
Sarah Varian	Marine Dimensions
Shane Colgan	Environmental Protection Agency (EPA)
Simon Berrow	Irish Whale and Dolphin Group (IWDG)
Tadhg O' Mahony	Environmental Protection Agency (EPA)
Tim Carey	Dún Laoghaire Rathdown County Council
Tom Doyle	University College Cork (UCC)
Tom O'Neill	Limerick County Council

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## Chapter 6. IMPLICATIONS FOR THE CULTURAL HERITAGE OF IRELAND'S COASTS AND INLAND WATERWAYS<sup>3</sup>

Author: Beatrice Kelly (Heritage Council)

### 6.1 Introduction

The potential impacts of climate change on the built and archaeological aspects of marine and inland waterways heritage in Ireland are considered in this chapter. These include structures specific to the coast and the inland waterways (e.g. harbours, piers, jetties, bridges, riverside buildings and quays, locks, dams, weirs, wrecks, lock keepers houses, harbour buildings and fisheries buildings, lighthouses, coast guard stations, Martello towers and other fortifications). The archaeological aspects include: features and sites found underwater; in intertidal zone, including estuaries; and along the coasts, rivers, lakes and canals. For ease, the term 'cultural heritage' will be used to cover built heritage and archaeology on land and underwater.

While the majority of Ireland's urban centres are located on the coast or inland waterways and represent a significant cumulative part of our cultural heritage resource, this chapter does not deal in detail with issues relating to urban centres as entities; instead it deals with individual structures. The issues relating to cultural heritage and climate change within urban areas are wider than the scope of this report, and will require further investigation. Many of the issues identified this chapter are however very relevant to these areas.

The chapter starts with a brief outline of the main research conducted on this subject and the potential impacts on built heritage and archaeology as identified by international organisations and studies. On the basis of these, a 'close-up' will be taken of the potential impacts on the cultural heritage features of the coastal zone and inland waterways in Ireland. General principles on adaptation and research for Ireland will be derived from the advice and recommendations proposed by the same organisations and studies. Research was carried out by consultation with key individuals in relevant agencies, by reviewing the relevant literature and websites.

Water has been identified as the main threat to cultural heritage as a result of climate change (Sabbioni, *et al.*, 2008) so the focus on Ireland's inland waterways and coasts seems appropriate in this light.

### 6.2 Climate change scenarios

The climate change scenarios for Ireland have been identified and discussed in detail in Chapters 3 and 4 and are summarised briefly here.

Ireland is likely to experience a potential mean temperature rise relative to the 1961-90 period of up to 2.1°C to 2.7°C by the 2080s, with the autumn months warming the most. Rainfall will become more seasonal with wetter winters and dryer but greyer summers. More extreme rain or precipitation events will occur, changing the current pattern of 'low duration, low intensity' to 'long duration, high intensity'. The likelihood of inland flooding<sup>4</sup> will increase as a result, in particular in the west and the midlands. The whole country will experience scarcity of water in the late summer and autumn, possibly more so in the east and south.

Sea levels are likely to rise by at least 18-59cm by the 2080s. This will be exacerbated by more storm events, storm surges, and increased wave energy. Coastal flooding, caused by a combination of these elements, and the resultant coastal erosion will be more prevalent, placing low-lying areas and soft coastlines at particular risk.

### 6.3 Current research

There is a generally expressed opinion through the literature that relatively little work has been done anywhere on the potential impacts of climate change on cultural heritage (Cassar, 2008). In particular, there has been little rigorous scientific investigation into the issue. The United Nations Educational, Scientific and Cultural Organisation (UNESCO), has examined and debated the potential impacts on World Heritage Sites (2008). The International Council for Monuments and Sites (ICOMOS) has drawn up guide-

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<sup>3</sup> Inland waterways refers to the navigable waterways, in use and disused, as defined in the Heritage Act, 1995.

<sup>4</sup> Different types of inland flooding include river flooding, ground water flooding, estuarial flooding, overland flow when the ground is so saturated that it can no longer absorb any more water, and flooding caused when artificial drainage systems can no longer cope with the quantity of water.

lines on adaptation (2008). A European-funded project, Noah's Ark, has examined the potential impacts across Europe and proposed adaptation measures for specific materials and built features (2007). In the UK work has been commissioned by English Heritage from the Sustainable Heritage Management department of University of London (Cassar 2005); English Heritage has also published guidance on dealing with flooding, coastal erosion (2003, 2004). The National Trust has examined the potential impacts on their properties, and on coastlines in their care (2007a, 2007b). Some detailed studies on the potential impacts on the different types of stone used in construction have been carried out too (e.g., *Engineering Heritage Futures*, Cassar and Hawkings 2007).

In Ireland, little work has been carried out to date on the potential impacts on cultural heritage, nor has this issue been discussed in any detail by any of the bodies involved in research in this area such as the Royal Irish Academy, the EPA, Met Eireann, NUI Maynooth. *Changing Shades of Green*, commissioned by the Irish American Climate Project (Sweeney, *et al.*, 2008), attempts to look at the environmental and cultural impacts of climate change in Ireland through interviews with people involved in culture, environmental management, alongside scientific explanations of the potential impacts of climate change. The purpose is to go beyond the information and give readers an insight into the feelings that the impacts and resultant changes may evoke. Although the perspectives it highlighted were stimulating, it does not tackle the issue of impacts on cultural heritage apart from potential physical changes to Ireland's iconic landscapes.

The Heritage Council has funded two research projects through its grant schemes, *Potential impacts of climate change on the decay and soiling of Irish Building Stone* by Jason Bolton, (2007) and *A vulnerability assessment of Ireland's coastal archaeological heritage* by Robin Edwards and Aidan O'Sullivan (2006). Other research is being carried out under the aegis of universities, for example a thesis on the climate change vulnerability of the Bru na Boinne World Heritage Site was submitted to Brandenburg Technical University by Cathy Daly in June 2008. No specific research on potential climate change impacts is being carried out by Waterways Ireland or by the Department of Environment, Heritage and Local Government (DEHLG), nor are there any immediate plans to do so (K. Brady, pers. comm.; P. Treacy, pers. comm.; J. McKeown, pers. comm.). However, in 2007 the Minister for the Environment, Heritage and Local Government, John Gormley, T.D., asked the Irish branch of ICOMOS to examine the effects of climate change on World Heritage Sites and heritage in general. The committee is planning to carry out this study during 2009. Despite this, we can conclude that the impacts of climate change on Irish heritage have been relatively unexplored.

Much of the international research has focused, or is focusing, on the impacts of climate change on specific materials used in the historic environment such as different stone types, mortars, timber, and metals, and, in particular, on the exacerbation of decay processes, and the interaction with atmospheric pollution (Noah's Ark, 2007; Cassar and Hawking, 2007). While building stone has been examined in Ireland (Bolton, 2007) it is not proposed to go into the detail of the impacts on specific materials in this chapter but to concentrate generally on the cultural heritage found along the waterways and in the coastal zone. However, the reader should note that an understanding of the processes of decay, and their exacerbation by changes to current climate patterns (e.g. salts crystallisation, humidity cycles, biocolonisation) on materials like stone, wood, mortars, metals and soils is vital to the understanding of how climate change can affect historic structures and buried archaeology. The need to carry out work in this area in Ireland is identified by Bolton (2007) and Daly (2008). In addition while much research outside Ireland has focused on potential impacts on coastal heritage, such as that by English Heritage, Historic Scotland, and the National Trust, no references have been found to research on historic navigations.

## 6.4 General impacts on cultural heritage

There are two types of impact on cultural heritage, direct ones from changes to our current climate regime, and indirect impacts including ones arising from cultural reactions, and changes to natural habitats and landscapes. Indirect effects can also arise from mitigation and adaptive responses, for example the construction of windfarms, planting of miscanthus, coastal defence projects, and flood alleviation schemes. The impacts of adaptive works to assist the survival of historic structures should also be considered an indirect effect. This includes works strengthening historic bridges, re-enforcing peat-constructed canal banks, and inserting new high-capacity rainwater goods on historic buildings.

The changes predicted for our current climate will exacerbate existing processes of decay and damage, but the greater frequency of extreme events like flooding may result in abrupt intensification of these processes, rather than a gradual increased rate of decay. This is already being noted by the National Trust at certain of their sites (2007a). As May Cassar states, 'Climate change often highlights long-standing preservation issues rather than creating new problems' (2005). As a result recommendations on adaptation measures for buildings relate to constant maintenance and repair, rather than dramatic intervention.

Cassar carried out a survey among cultural heritage professionals in 2005 for English Heritage which resulted in a clear consensus on the changes causing greatest concern: i) temperature change and associated changes in relative humidity; ii) changes in rainfall patterns, iii); fluvial and runoff flooding; and iv) coastal loss and flooding. While these have obvious impacts on built structures and monuments, the potential for known and unidentified archaeological sites on land and underwater to be degraded by these processes is also very high. The assumption of 'preservation in situ' is now being questioned for certain sites by the archaeological profession in the UK due to potential changes in wet/dry cycles, soil acidity, and ground stability (Cassar, 2005).

Table 6.1 presents a overview of the climate change risks that threaten European cultural heritage. It is adapted from Noah's Ark *Guidelines On The Adaptation To Climate Change 2007* and May Cassar's report, *Climate Change and the Historic Environment*.

**Table 6.1: Potential impacts on cultural heritage within Europe (Noah's Ark, 2007; and May Cassar, 2005)**

	Climate change risk	Physical and social impacts on cultural heritage
<b>Atmospheric moisture change</b>	<ul style="list-style-type: none"> <li>■ Flooding (sea, river)</li> <li>■ Intense rainfall especially in winter</li> <li>■ Changes in water table levels</li> <li>■ Changes in soil chemistry</li> <li>■ Changes in humidity cycles</li> <li>■ Increases in time of wetness</li> <li>■ Sea salt chlorides</li> </ul>	<ul style="list-style-type: none"> <li>■ Erosion of inorganic and organic materials due to flood waters</li> <li>■ Physical changes to porous building materials and finishes due to rising damp</li> <li>■ Damage due to faulty or inadequate water disposal systems; historic rain water goods not capable of handling heavy rain and often difficult to access, maintain and adjust</li> <li>■ Inappropriate adaptation to allow structures to remain in use</li> <li>■ pH changes to buried archaeological evidence</li> <li>■ Subsoil instability, ground heave and subsidence</li> <li>■ Loss of stratigraphic integrity due to cracking and heaving from changes in sediment moisture</li> <li>■ Loss of data preserved in waterlogged/anaerobic/anoxic conditions</li> <li>■ Corrosion of metals</li> <li>■ Crystallisation and dissolution of salts caused by wetting and drying, affecting standing structures, archaeology, frescos, etc</li> <li>■ Changes in relative humidity cycles causing splitting, cracking, flaking and dusting of materials and surfaces</li> <li>■ Biological attack of organic materials by insects, moulds, fungi, invasive species like termites</li> </ul>
<b>Wind</b>	<ul style="list-style-type: none"> <li>■ Wind-driven rain</li> <li>■ Wind-driven sand</li> <li>■ Wind transported salt</li> <li>■ Wind, gusts and changes in direction</li> </ul>	<ul style="list-style-type: none"> <li>■ Penetrative moisture into porous cultural heritage materials</li> <li>■ Static and dynamic loading of historic and archaeological structures</li> <li>■ Structural damage and collapse</li> <li>■ Deterioration of surfaces due to erosion</li> </ul>
<b>Sea level rise</b>	<ul style="list-style-type: none"> <li>■ Coastal flooding</li> <li>■ Sea water incursion</li> </ul>	<ul style="list-style-type: none"> <li>■ Coastal erosion and loss of sites</li> <li>■ Permanent submersion of low lying areas</li> <li>■ Intermittent introduction of large masses of 'strange' water to sites which may disturb the metastable equilibrium between artefacts and soil</li> <li>■ Population migrations</li> <li>■ Disruption of communities, breakdown of social interactions, loss of rituals</li> </ul>
<b>Temperature change</b>	<ul style="list-style-type: none"> <li>■ Diurnal, seasonal, extreme events</li> <li>■ Changes in freeze-thaw and ice storms, and increase in wet frost</li> </ul>	<ul style="list-style-type: none"> <li>■ Freeze-thaw/frost damage</li> <li>■ Biochemical deterioration</li> <li>■ Inappropriate adaptation to allow structures to remain in use</li> <li>■ Deterioration of facades due to thermal stress</li> <li>■ Damage inside brick, stone, ceramics that get wet and frozen</li> </ul>

	Climate change risk	Physical and social impacts on cultural heritage
Climate and pollution acting together	<ul style="list-style-type: none"> <li>■ pH precipitation</li> <li>■ Changes in the deposition of pollutants</li> </ul>	<ul style="list-style-type: none"> <li>■ Stone recession by dissolution of carbonates</li> <li>■ Blackening of materials</li> <li>■ Corrosion of metals</li> <li>■ Influence of bio-colonisation</li> </ul>
Climate and biological effects	<ul style="list-style-type: none"> <li>■ Proliferation of invasive species</li> <li>■ Spread of existing and new species of insects</li> <li>■ Increases in mould growth</li> <li>■ Changes to lichen colonies on buildings</li> <li>■ Decline of original plant material</li> </ul>	<ul style="list-style-type: none"> <li>■ Changes in the natural heritage values of cultural heritage sites</li> <li>■ Changes in the appearance of landscapes</li> <li>■ Transformation of communities</li> <li>■ Changes in traditional livelihoods</li> <li>■ Collapse of structural timber and timber finishes</li> <li>■ Reduction in availability of native species for the repair and maintenance of buildings</li> </ul>

The main threats to cultural heritage along the inland waterways and in maritime areas in Ireland are presented in Table 6.2 below:

*Table 6.2 Main threats from climate change to cultural heritage of the inland waterways and maritime area in Ireland*

Climate Change	Impact	Aspect of heritage that could be affected
Greater seasonality in rain fall patterns Increased rainfall events	An increase in flood events both fluvial and coastal, Changes to hydrology and river flow More extreme humidity cycles in soils and buildings Changes to ground stability	Heritage structures, inland and coastal Known and unknown archaeological sites on land, inland and coastal Navigations and related structures, Underwater archaeology of rivers and lakes
Sea level rise	Increased rates of coastal flooding and erosion Changes in tidal range Changes to river profiles (erosion, scouring, deposition)	Land-based coastal archaeology Intertidal archaeology, Heritage structures along the coast, and estuaries and of affected rivers Underwater archaeology of coasts and affected rivers
Extreme winds, and storm events Increases in storm surges	Increased rates of coastal erosion Changes in coastal sediment transport Increases in wave power	Lake and coastal navigation and associated structures, Heritage structures of coasts and lakes Land-based archaeology of coasts and lakes

The potential damage caused by a combination of these impacts must be considered. For example, if river flood events are more severe with higher water velocities and higher water levels we may see structures failing more frequently.

## 6.5 Inland waterways: features relating to historic navigations, and the archaeology of navigable inland waterways including the Shannon Lakes.

### 6.5.1 Research

No research has been identified in the course of this review on the impacts of climate change on historic waterways in Europe. Work is being carried out by the international association for inland and maritime navigation and ports, PIANC<sup>5</sup>, on the potential impacts for international freight transport on continental Europe (2007). Under its revised remit, the Inland Waterways Advisory Council (IWAC) includes climate change (IWAC, 2008a) and is planning to undertake work on this area in 2009 ( John Edwards, pers. comm.), though not specifically on historic navigations. In its 2007 review, IWAC states that inland waterways will be impacted significantly by climate change and requests the UK Government to give this issue more attention in any future vision for inland

<sup>5</sup> Permanent International Association of Navigation Congresses



waterways (2007). British Waterways is not carrying out any specific research in relation to historic navigations (Glenn Millar, pers. comm.).

### 6.5.2 Impacts on inland waterways

The principal navigable waterways in use at present in Ireland are: the Shannon Navigation; the Shannon Erne Canal; the Royal and Grand Canals; and the Barrow line and River Barrow Navigation. Navigation takes place on the River Suir up to Carrick on Suir, and on Lough Corrib. Disused navigations include the rivers Boyne, and Blackwater and the upper reaches of the Suir, as well as the Slaney. There are plans to restore the Ulster Canal to Clones and eventually to Lough Neagh. The historic features of the navigable waterways and their water supply are the focus of this section. The navigations were constructed during early eighteenth and nineteenth centuries and therefore contain a stock of important cultural heritage relating to Ireland's industries, and engineering and transport history.

The principal effects of climate change that will impact directly on the navigable waters are changes to current patterns of river flow and water supply, intense rainfall and flooding, and sea level rise. Although all of the above are inter-related - changes in rainfall patterns affect river flows and water supply, as well as contributing to flood events - this section will examine each event under separate headings. Indirect impacts on inland waterways include flood defence works, changes to vegetation and landscape which will also be explored in this section.

### 6.5.3 Intense rainfall events and flooding

There are different types of inland flooding, all of which are caused by intense rainfall and all of which have direct impacts on the navigable waterways, separately and in combination. River flooding may cause changes to water flow and velocity (in addition to causing a river to break its banks) while the canals are more vulnerable to abrupt changes in water levels due to rainfall and or run-off.

Intense rainfall and the resultant flooding has the potential to affect the stability of navigational structures (e.g., locks, bridges, weirs, and river and canal banks). The banks of the canals themselves might be unstable, in particular, those sections crossing the mid-land bogs. The Grand Canal crosses the Bog of Allan for a stretch of about 20 miles with embankments constructed from peat on either side, a legacy of the engineering arguments of the later eighteenth century. Following the advice of John Smeaton, 'Avoid a bog if you can, but by all means possible, the going deep into it,' meant that the canal was built at the same level as the original bog but due to subsidence, it needed from the start great bog embankments to hold it up (Delany, 1995). These were problematic from the outset, and are still one of the features of greatest risk in the stock of Irish waterways (John McKeown, pers. comm.). They stand up to 9m high at certain places. In January 1989 there was a serious slippage of sections of these embankments near Edenderry; as a result of piezometric pressure the peat within the embankments can liquefy and move (in part caused by raised water tables). They were rebuilt with vertical drains to prevent the same event reoccurring. However, these bog embankments are high risk features, which Waterways Ireland monitor constantly, and may require more detailed monitoring if intense rainfall events become more frequent.

The water levels on the canals can be affected by intense rainfall, as occurred in summer 2008. The Grand Canal has two bogs to the north of it which drain southwards. On 16 August of that year, the quantity of rain that fell caused over-flow flooding from the bogs into the canal, with the result that the canal levels had to be man-managed through the locks down into the Shannon. In Dublin the water levels started to overtop the canal banks at the locks around Inchicore and also had to be managed to avoid disaster. This is a very labour-intensive process, and as excessive rainfall can take place at any time, as in this case (over a weekend), waterways staff have to be ready to react outside of normal working hours. (John McKeown, pers. comm.).

In relation to flooding, many features on the waterways are designed to be immersed in water (such as locks, bridges, jetties, and harbours). Shallow flooding is not likely to cause significant damage but increased water flow can cause erosion of foundations to bridges, as well as increasing the loading on historic structures. The effects of a build up of heavy flotsam can be similar. Heavy flotsam will also increase loading on structures and large items such as tree trunks also have the potential to damage lock features and weirs (Bolton, 2007; Noah's Ark, 2007). A layer of dirt may be left on stone structures by water abrasion but the main risk to stone-built structures is likely to happen after the flood event, as a result of rapid drying and water saturation of masonry (Bolton, 2007).

Increased run-off of pollutants from roads and agriculture into the waterways after intense rainfall may also exacerbate decay of historic building stone in locks, bridges and jetties, as well as affecting water quality. Archaeological monuments in the vicinity of inland navigations may experience higher frequency of flooding too. Cathy Daly estimates that at current flood levels 10% of recorded monuments at Bru na Boinne are already at risk from flood waters (2008). Many of these may not be severely affected as the monuments referred to above that are related directly to the river and canal (e.g. bridges, weirs and mills). However, based on future scenarios, this figure is likely to rise, and will affect structures not designed for watery environments. Daly recommends a site survey to assess sensitivity and exposure to flood damage. (Daly, 2008). In relation to wetland and underwater archaeological sites – crannogs, medieval harbours, dugout boats and wrecks, early bridge foundations – changes in current patterns of drying and wetting may speed up decay, and cause changes to archaeological stratigraphy; unidentified sites are most at risk (CBA, 2008, Cassar, 2005). Sites around the Shannon lakes, or on islands may suffer erosion from raised water levels, and more frequent storm events.

Changes in sea levels will have impacts on inland waterways too, on flood events and on river profiles. Flooding may be exacerbated by rises in sea levels, especially when high river flows combine with spring tides, and/or storm surges. This will cause water to be forced up the river channel and possibly flood over the river banks (DEHLG/OPW, 2008). Concerns are being expressed about the ability of the canal banks of the Boyne Navigation to withstand the rises in seasonal flooding, which may increase with predicted rises in sea levels and its impacts on the river levels (Daly, 2008). River profiles will also be affected by sea level rise (SLR), thus changing erosion and deposition patterns both upstream and within estuaries (Niall McManus pers. comm.). Bridges and other navigational structures as well as underwater archaeological sites should be monitored for erosion or deposition caused by the interaction of river waters with rising sea levels.

#### 6.5.4 River flow

The future changes in fluctuation of river flows will also affect our inland waterways. Low flow at times of drought will prevent navigation; similarly high flow will result in higher water velocity which can render navigation unsafe as happened at times during the summer of 2006 and 2008 (C. Becker, *pers.comm.*) Studies have been conducted in Ireland on river flow (see chapter 4, section 4) which examine the change in streamflow of different catchment responses, whether it is surface water dominant or has ground water storage capacity. This study includes the rivers Barrow, Suck, Suir and Boyne, two current navigations, two disused. As stated in Chapter 4, those rivers which are fed from groundwater catchments are likely to experience less of a reduction of flow in the summer like the Suir, Suck and Barrow. Chapter 4 refers to the potential impacts on navigation with the reduction in river flow and how it is likely to impact the navigation of the Barrow and the Suir. According to figure 4.3 in Chapter 4, the Boyne will be severely affected by low flow in summer, an issue that should be examined if the Boyne Canal navigation is considered for full restoration. Likewise boating on currently underused navigations, for instance the Suir, may become more attractive in the next 20-30 years than presently due to factors such as greater resilience to fluctuations in river flow.

Changes in river flow may also affect the loading on historic navigational structures such as bridges, quays, locks and weirs. This is illustrated by recent concerns about the state of O'Connell Bridge in Dublin where cracks appeared during the summer of 2008. A consultant structural engineer, Dr Peter McCabe is quoted as saying that he suspects that the foundations of the bridge piers could have subsided due to the recent strong flow of the river (Hutton, 2008).

Underwater archaeology can be affected by increased river flows and changes in velocity, causing erosion or deposition of sediment which may render sites and structures more vulnerable to damage. In some cases, though, deposition of sediment may give additional protection. Some areas with potential for underwater archaeology have been identified but more field work would be helpful to assess the importance of this issue (K. Brady, *pers. comm.*).

The nature of navigation on rivers such as the Shannon, Barrow and Boyne may also be affected by flooding where higher flows and faster water velocity may result in the use of higher horse power engines on boats to cope (B. Cassells, *pers. comm.*). Depending on the shape of the boats, and how they are handled, this in turn may result in increased boat wash (Heritage Council, 2006). This would result in further negative impacts on navigational channels through the undermining of banks, and on natural heritage such as nesting birds, aquatic vegetation and fish life, as well as raising safety issues.

#### 6.5.5 Water supply

Water supply is critical for navigation, an activity which is central to the living heritage of the waterways. IWAC (2007) identifies water supply as the principal issue for inland waterways, pointing out that with lower river flows, and flash flooding, the depend-

ability of some traditional water supplies are in question. According to IWAC, the Environment Agency has already warned the navigation authorities in the UK that they will have to apply for abstraction licences in the future. IWAC deduces that some waterways will find it difficult to have sufficient water supplies in the future, in particular with competition from an increasing human population and the trend of living alone, as well as natural habitats requiring a buffer from drier conditions too. IWAC is calling for some 'robust' modelling to identify the likely effects and the most vulnerable waterways.

In Ireland, given the availability of predicted patterns of rainfall and drought for the next 100 years, the likelihood of reduced water supply to the canals during the summer must be investigated for its impacts on navigation. Drought and evaporation could impact on the water supply to canals, such as the Royal and Grand Canals which are dependent on a single summit source and local feeder systems. Current demand for water abstraction for human consumption has narrowed the scope for additional supply from Lough Owel to the Royal Canal so an alternative source from Lough Ennell is being investigated. The principal supply for the Grand Canal is taken from Pollardstown Fen, while satisfactory at time of writing (2008), is vulnerable to climate change. The condition of the fen is being monitored in relation to possible effects on ground water flows caused to the N7 cutting. The plans to increase the water supply to the Greater Dublin area, possibly from abstraction from the River Shannon, may also place additional pressure on water supply to inland waterways in the east of the country, (Dublin City Council, 2008). Modelling will be needed to look at the water supply to these and to identify vulnerable water supplies from an inland waterways perspective.

#### 6.5.6 Indirect impacts of flood mitigation works on historic navigations

The impact of flood defence works in historic towns is an indirect impact of climate change and has already been identified in the UK (English Heritage, 2006) as a threat to cultural heritage, and has been noted in practice in Ireland (K. Brady, *pers. comm.*). While town centres require protection from frequent flooding, flood defences that take no consideration of historic elements, especially in relation to navigation, may be a serious threat to this aspect of heritage. The planned walling along the quays in Clonmel and Carlow will change their nature greatly. The removal of historic fabric, usually of an industrial nature like bridges and mills, should be considered as a last resort. Lessons learnt from towns or cities where major infrastructural work has already taken place on rivers – Limerick (main drainage scheme), Kilkenny and Carrick on Suir (flood relief schemes) – will help authorities design flood defences that either include historic navigational features or minimise damage to the integrity of river cultural heritage. In the UK, emphasis has moved from hard flood defences to more natural defences such as providing rivers space to flood in their natural flood plains. The OPW and the Department of Environment, Heritage and Local Government (DEHLG) are trying to promote similar policies here too by recommending no further development in flood plains adjacent to towns and villages (2008). Should these policies be successful, there will be an indirect but significant gain to the historic environment through the avoidance of major flood defence structures or the removal of historic features.

#### 6.5.7 Changes in vegetation and landscapes

Changes to the vegetation along the towpaths, and changes to agricultural practice in the adjacent countryside such as the planting of new crops like miscanthus and maize will also impact on the inland waterways by changing the traditional landscapes and context of the navigations. Warmer water temperatures will aid the spread of invasive species in the water, and navigations may be constricted by more weed growth, exacerbated by the profile of the canals being shallower than when in commercial use. This will lead either to higher weed harvesting costs or to greater use of chemical controls if the navigation is to be maintained.

#### 6.5.8 Conclusions

The potential impacts on inland waterways are at the moment conjectural, due to a lack of data on current status, and are based upon scenarios derived from the natural environment, as well as extrapolation from impacts observed in or predicted for built historic structures on land. To determine the impacts and sensitivity to impacts the following actions are required:

- i. baseline surveys of historic structures and the establishment of monitoring schemes to see if impacts are already identifiable, (including indirect impacts such as flood relief schemes);
- ii. mapping/modelling of vulnerable areas (water supply, river flow) and of vulnerable structures (bog embankments, historic bridges, locks);
- iii. planning for risk management of historic structures, and historic urban centres; and
- iv. training staff of waterways and local authorities to deal with waterways emergencies.

Waterways Ireland (WI) are already engaged in risk management of the navigations, and their staff are able to cope with emer-

gencies as has been demonstrated in the summer of 2008. However, not all waterways are under WI remit and, of those which are, WI are not responsible for managing all aspects (e.g. water levels on the Shannon are the responsibility of the ESB). As a consequence, it is likely that detailed monitoring and modelling, and subsequent procedural agreements will be needed to manage the specific impacts on cultural heritage.

## 6.6 Coastal heritage

### 6.6.1 General impacts

It is generally recognised that of all heritage resource, coastal heritage is at greatest risk (UNESCO, ICOMOS<sup>6</sup>, CBA<sup>7</sup>). Major impacts on coastal cultural heritage are likely to occur from projected sea level rise (SLR), increased coastal erosion and coastal flooding, more frequent storm events and greater wave energy. Coastal erosion, in particular, will be one of the most widespread and demanding impacts of climate change, posing challenges on what to protect, with potentially conflicting demands emerging within the cultural and natural heritage resource. The National Trust survey has indicated that by 2100 up to 60% of the coastline it manages will be eroded inland, in some places by as much as 200m. Up to 500 sites and buildings are at risk in its estate which makes up about 10% of the coastline of England, Wales and Northern Ireland (2007a). Heyworth and Chitty (2008) state that built heritage will experience more extreme impacts than buried archaeology while ICOMOS recommends that plans are made to prepare sites for a submerged future due to sea level rise or damage from wave wash or storm surge (2008). ICOMOS is of the opinion that coastal fortifications are at high risk, principally those built in the twentieth century of non-durable materials such as steel, and reinforced concrete.

### 6.6.2 Ireland's coastal heritage

The coastal area of Ireland has been occupied since the end of the last Ice Age (c.8000 BP) resulting in a rich varied cultural heritage resource around the island. Structures specific to the coast include: harbours; piers; jetties; harbour buildings and fisheries buildings; light houses; coast guard stations dating from the Middle Ages to the twentieth century; and coastal fortifications including Martello towers, naval bases, and forts with associated features dating from the Iron Age to the twentieth century (see Nairn, 2005). Archaeological sites include wrecks, middens, promontory forts, habitation areas, fishtraps, and other evidence of activities associated with exploiting sea shore resources like seaweed and shellfish (O'Sullivan and Breen, 2007). Lack of appreciation of Ireland's maritime heritage has resulted in this resource being ignored by archaeologists and other heritage specialists and a consequence little is known about the character, range and vulnerability of identified coastal sites. (Edwards and O'Sullivan, 2007). Pioneering surveys of Strangford Lough, and the Shannon Estuary, in the past 15 years give an indication of the range of evidence that could be found in estuarine areas (O'Sullivan 2001, McErlean *et al.*, 2002). Some counties are attempting to fill this research gap (e.g. Fingal County Council and Dun Laoghaire Rathdown (DLR) County Council's survey of Martello towers, the County Clare survey of piers in 2005-7, and DLR survey of coastal heritage in 2007). Some 74 hitherto unrecorded sites were identified by fieldwork on this last survey along the south Dublin coastline, demonstrating the value of field surveys, especially in the light of the inaccuracy of many historic map sources for the inter-tidal and coastal areas (Bolton, 2008). These surveys demonstrate the variety of sites to be found along the coast from military and industrial sites, and recreational features such as bathing places. It is interesting to note that Clare County Council has also carried out a further survey on piers in County Clare, looking at the use of inappropriate materials in repairing historic piers. Not only do these materials detract from the historic character, they may place such stress on the original construction fabric that increased pressure from intense weather events could cause greater damage than if no repairs had been carried out. This has already occurred on the South Wall in Dublin Bay where repairs carried out in the 1990s have caused the wall to spilt under pressure from storm energy (Gráinne Shaffrey, pers. comm.). Interestingly none of these surveys allude to the likely impacts of climate change in the near future. As identified in Chapter 4, approximately 680km<sup>2</sup> of the Republic of Ireland coastline could be affected by flooding and storm events. It is clear, therefore, that there is an urgent need for a baseline survey along the coast to identify and quantify the cultural heritage resource that could be at risk. This will be discussed in more detail later in the chapter.

Another issue to consider is the coastal or estuarine location of the majority of our urban areas. The historic reasons for their development mean that the majority of Ireland's cities and towns are located on the coast, at river mouths or further up river estuaries. These areas present a significant cultural heritage resource, both individually through particular structures or individual towns, and cumulatively over time and on a geographic basis. This will need to be taken account of in any discussions on how best to plan for their future protection.

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<sup>6</sup> International Council for Monuments and Sites

<sup>7</sup> Council for British Archaeology

### 6.6.3 Sea level rise and associated processes - flooding and coastal erosion

Sea levels are predicted to rise by 18-59cm around Ireland in the next 100 years, as explained in Chapter 4. Recent research states this may be even higher (Grinsted, A. *et al*, 2008). However, it is the associated factors such as increased coastal flooding and erosion, increased wave and storm activity, the rise in the tidal range, and importantly the extension inland of the inter-tidal zone that pose the main threats to built heritage on the coast. Impacts will vary depending on coastline morphology with features such as estuaries, coastal plains, and coastal wetlands at high risk from the impacts. These areas are often rich in archaeology due to the valuable resources and functions they provide to humans, and as a result are also the location for Ireland's major urban centres.

Coastal cultural heritage sites fall into three categories based on their location: i) land-based; ii) intertidal sites; and iii) underwater or submerged sites including wrecks. Sites or structures in the intertidal area are apparently at greatest risk of damage by the sea due to undermining, wave action, corrosion, wet-dry cycles, and sea spray (Bolton 2007). One of the effects of coastal erosion is to move the inter-tidal zone inwards which results in cultural heritage sites being more exposed to an aggressive environment. Bolton notes in his field work along the south Dublin coast that the areas at the high-water mark and intertidal zone contain more phenomena associated with decay than do other coastal areas. Many structures in inter-tidal areas were designed for a water-based environment such as harbours, jetties and piers, lighthouses and some coastal fortifications but not to withstand the new stresses presented by increasing sea levels and tidal range, and storm intensity. Anecdotal evidence noted by the underwater unit within the DEHLG shows that a greater number of wrecks were uncovered in the intertidal zone during the summer of 2007 than in other years (K. Brady, pers. comm.). Once uncovered they are vulnerable to being broken up by wave energy and curious humans.

Land-based sites such as signal towers, coastguard stations, Martello towers, and other coastal fortifications are likely to suffer severe impacts from coastal erosion and flooding. More frequent storm events and increased wave energy will exacerbate these processes especially when combined with storm surges. These impacts will vary depending on the character of the coastline on which they are located, and the coastal processes that occur within the relevant section of shoreline, including sediment movement, current direction, exposure to wind and wave power. An understanding of coastal processes, and how they interact within specific shoreline segments is vital to the planning of responses to coastal change, and subsequently to the management of coastal heritage. Usually shoreline studies focus on soft coastlines as they are seen as more vulnerable. However Bolton (2007) points out that rocky coastlines are not uniform and different rock types display different durability characteristics. He cites the example of the history of collapse of the quartzite and greywacke cliffs at Bray Head, County Wicklow, and the subsequent relocation of the railway line. Based on his recommendations, a geotechnical slope-stability assessment should be carried out on cliffs where archaeological sites of high interest are located.

Underwater sites are also affected by coastal processes. Increased storm intensity and more frequent storm events may change patterns of sediment erosion and deposition in inshore waters. Wrecks may be exposed making them vulnerable to damage from shipping, or treasure hunting and careless exploration by divers. As storm frequency increases, sites that were exposed on a long term cycle such as every 20-50 years may be exposed on a much more frequent basis. Extreme weather also limits the possibility of carrying out rescue excavations. So while more sites may become exposed, there may be a reduction in the number of days suitable for survey and excavation work (K. Brady, pers. comm.).

Recent survey work of Ireland's inshore waters carried out as part of the INFOMAR project has allowed the identification of the location of about 250 wrecks. The techniques used and resolution of the mapping favours the larger metal wrecks to submerged wooden ones such as Armada wrecks (K. Brady, pers. comm.). This new mapping is creating an accurate bathymetry, providing a much needed baseline of the seabed by which changes in coastal processes like sediment movement, erosion and accretion patterns can be monitored. The first volume of the Shipwreck Inventory has been recently published (Brady, 2009), and goes some way to providing the critical baseline information we need to manage this resource.

### 6.6.4 Vulnerability of Ireland's coastal archaeology

Despite the lack of baseline knowledge on Ireland's cultural heritage coastal resource, Robin Edwards and Aidan O'Sullivan have started to study the Irish coast line from paleohistory to the present for the purpose of assessing Relative Sea Level (RSL) changes and potential vulnerability of coastal archaeology in selected regions in Ireland (2007). To do so, they reconstructed the changes in Ireland's coastline over the last 20,000 years using a newly developed glacial rebound model and combined these data with existing geological and archaeological information. The results identified the inlets of southern Ireland, the Shannon Estuary and the coastline of Mayo, Connemara and associated islands as vulnerable areas with high archaeological potential in part due to the submergence of low-lying coastal land in these areas.

The inlets of southern Ireland are soft coastlines made of glacial materials and are, according to O'Sullivan and Edwards, vulnerable to relatively minor changes in sea level or wind/ wave processes. The reconstructed RSL or paleogeographies suggest that much land has been lost around Wexford and Waterford which fits the modern pattern of extensive rates of coastal erosion in these areas, with the particularly dramatic example of Rosslare Village in the 1920s.

The Shannon Estuary is experiencing long term subsidence and thus is particularly susceptible to alterations in sea level. The study shows that it has already experienced great change in RSL and is therefore following a long-standing pattern. The Mayo and Connemara coasts are a mixture of rocky cliffs, and sheltered bays and inlets of softer glacial material. Like the other two areas, it has experienced RSL rise resulting in the creation of islands. O'Sullivan and Edwards identify a potential in this area to examine how people responded to this loss of land, flooding and restricted communication.

They point out that coastal processes will have the most dramatic effects in low-lying vulnerable environments along the coast, which are frequently associated with archaeological sites: submerged landscapes, estuarine mudflats and salt marshes, sand dunes and coastal machairs, and low-lying earthen bluffs. This presents a paradox, since the erosion and uncovering of archaeological sites expands current knowledge of human activity along the coast and there is an urgent need to record these sites before they are eroded. The authors hope that, by prioritising areas at greatest risk and by identifying the coastlines of high archaeological potential, these losses can be minimised.

#### 6.6.4 Indirect impacts of climate change

Coastal heritage is often threatened by human interventions intended to protect against coastal erosion and flooding (Heyworth and Chitty (2008), English Heritage (2006), Edwards and O'Sullivan (2007) as is the case for inland waterways. Hard engineering works on shorelines and estuarine areas can impact directly on archaeological sites and heritage structures, either removing them entirely or compromising their historic character. Changes in sediment erosion and deposition patterns caused by hard interventions can also undermine or expose sites further along the coast, while inter-tidal sites in habitats like salt marshes or mud flats are vulnerable to coastal squeeze. Soft engineering options like 'managed realignment' also threaten cultural heritage. The creation of new coastal wetlands may submerge sites and features, raising a conflict between the needs of cultural and natural heritage. English Heritage has excavated sites like Blakeney Chapel in Norfolk which would have been eroded by a 'managed realignment scheme' (Murphy, *et al.*, 2008). Mitigation measures such as wind farms may impact on wrecks or submerged landscapes, and barrages schemes such as is proposed for the Severn estuary in the UK will impact on sites too (Murphy, *et al.*, 2008). However, correct implementation of site selection studies and the SEA and EIA processes should help avoid significant sites.

In Ireland, one of the greatest difficulties in managing coastal heritage arises from current public attitudes, which being ill-informed of coastal processes, often results in demands to government for hard defences of the coastline (Devoy, 2008; Edwards and O'Sullivan, 2007). Devoy points out that there are low levels of awareness and understanding of coastal processes and vulnerabilities, which is a constraint on Ireland's ability to cope with the impacts of SLR. The policy vacuum in this area, in particular in relation to Integrated Coastal Zone Management, is one of the greatest threats to heritage as well as to other activities along the coast. 'In essence, Ireland's coastal vulnerability lies more with the attitudes of the people to ICZM than in any physical susceptibility of the coast for response to climate change.' (Devoy, 2008).

#### 6.6.5 How to plan for protection – examples from the UK and Northern Ireland

Three examples are outlined here to show a variety of responses by different types of organisations: The Rapid Coastal Zone Assessment Surveys of English Heritage, the National Trust, *Shifting Shores study*, and the Shorewatch scheme in Scotland.

i) According to English Heritage (EH), the management of conserving coastal heritage depends on improved information of the resource (Murphy, 2005). To fulfil this, they are commissioning Rapid Coastal Zone Assessment Surveys (RCZAS), which inform Shoreline Management Plans (SMPs), and Estuary Management Plans, about the Environment Agency's plans for managing coastal flooding and coastal protection. In addition these RCZAS also inform EH strategies for long-term monitoring, and provide a baseline for future research. The surveys consist of desk and field work. While difficult choices cannot be avoided, these surveys and their inclusion in SMPs provide a long term robust framework within which to take decisions.

ii) The National Trust in Northern Ireland (NI) commissioned a detailed study on the potential impacts of climate change on its three coastal sites, the Giant's Causeway World Heritage Site, The north east corner of Strangford Lough, and Murlough National Nature



Reserve on the County Down coast (NT 2007b). These sites are described as acting ‘like a canary in a coalmine’ as they identify issues to be addressed at many of the NI coastland sites. The National Trust is taking a long-term view, working with natural coastal change as far as possible, rather than the traditional response of protecting existing coast lines by hard engineering processes, which are regarded as the last resort. Nevertheless the Trust will consider the social and economic impacts alongside the environmental impacts of the decisions they take on the coast. An example is cited of working with nature at the Portstewart Strand visitor centre which is designed to be taken down and relocated with minimal impacts, while their activity centre on the Norfolk coast at Brancaster is designed to cope with frequent coastal flooding.

iii) At least 12,000 sites may be at risk from coastal erosion in Scotland according to Shorewatch, a project where sites are reported and recorded by voluntary groups along the coast (Shorewatch). Groups ranging from historical and archaeological groups, community groups and youth groups are carrying out this work. The project is co-ordinated by SCAPE (Scottish Archaeology and the Problem of Erosion) which provides training and recording resources to the groups. The project was set up in 2002 and is supported by Historic Scotland, the University of Saint Andrews, the Crown Estate, and the Heritage Lottery fund. The coastal zone assessment surveys carried out by SCAPE have identified over 11,000 sites around the coast and so far, only about 30% of the Scottish coast has been examined. The Shorescape project demonstrates the positive benefits of involving people directly in archaeological data gathering.

#### 6.6.6 Research needs

Changes to our coastline caused by climatic change pose a major threat to our cultural heritage resource. Current levels of knowledge of this resource are limited, which makes managing it nearly impossible. The work carried out by Clare and Dun Laoghaire Rathdown County Councils, referred to earlier in this section, gives an indication of the extent, and variety of this resource, as do the surveys of the Shannon Estuary and Strangford Lough. Desk research needs to be conducted to document and assess known coastal archaeological sites along with coastal surveys. Edwards and O Sullivan (2007) recommend bathymetric and geophysical surveys in key locations to identify areas of greatest archaeological potential or vulnerability. The existence of data sets of the coastline, including some inshore mapping (INFOMAR) and LIDAR coastal surveys, coastal aerial photography, erosion and coastal flood maps will assist in establishing these inventories. Many of these data have been generated as part of the Irish Coastal Protection Strategy Study (ICPSS).

Current constraints on managing the cultural heritage of the coast include a lack of baseline data on sites in the coastal zone, publicly-held attitudes to coastal protection of ‘hold the line’ (Devoy, 2008), a lack of financial and human resources, and most importantly, the lack of recognition by policy makers, and decision takers for the extent of the threat. Until some of these are addressed, it will be hard to take a systematic approach to management of change of this resource.

### 6.7 Adaptation

#### 6.7.1 General principles

Adaptation is defined by the International Panel on Climate Change (IPCC) as the ‘adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects which moderates harm or exploits beneficial opportunities.’ (2004). This section will discuss adaptation measures proposed by agencies and organisations abroad and assess how they may best be used for the conservation of the cultural heritage of Ireland’s inland waterways and coasts.

Current adaptation measures may be informed by evidence from archaeology and heritage structures showing how previous generations coped with earlier environmental and climate change. Edwards and O’Sullivan (2007) identify Clew Bay as an area that offers evidence of how people coped with rising waters and the creation of islands, and resultant isolation of communities. The archaeological record can help us realise that during previous changes to our climatic patterns we have been capable of finding ways to adapt (Heyworth and Chitty, 2008). Early modern bridge building can indicate to us the flooding extent in earlier times, for example, the Finn River bridges in County Donegal (Colm Murray, *pers. comm.*). The location of earlier settlements in the vicinity of flood plains can help indicate the extent of flooding. Traditional building materials such as lime mortar may assist in making buildings more resilient and provide other sustainable solutions (Chitty and Heyworth, 2008). Navigations may help dispose of flood waters in flood alleviation schemes (IWAC, 2008).

In May 2007, ICOMOS brought out a resolution on climate change and its impacts on cultural heritage which sums up the issues and actions that should ensure successful adaptation strategies for cultural heritage. ICOMOS:

- Acknowledges the complex issue of impact of climate change on cultural heritage which requires sustained research, studies and documentation on multidisciplinary basis
- Recognises the need to assess the risks to cultural heritage
- Suggests that this assessment be done at macro level - mapping heritage that would be at risk and at micro level by analysing the impacts on specific sites, and recommending appropriate adaptation strategies
- Recommends that climate change adaptation strategies for cultural heritage should be mainstreamed into existing methodologies for preservation and conservation of sites, landscapes, living traditions etc
- The cultural heritage needs and concerns should also be mainstreamed into institutional policies and processes for minimizing disaster

Further ICOMOS recommendations on adaptation were made in 2008:

- Need to raise awareness and understanding of climate change
- Need to keep in mind the historic evolution of cultures to environmental change
- Need for more training for heritage practitioners in relation to climate change, to factor it into management and development plans
- Need to make a space in the debate for the community voice
- Need to interpret global climate change (GCC). GCC is creating a new heritage of loss. Its interpretation must emphasise climate's continued impact on human culture, and the changes occurring at the moment

These principles are applicable to cultural heritage in all forms and offer a clear way forward for us in Ireland.

The Noah's Ark project published a series of guiding principles in relation to historic buildings and structures which bring in a series of themes that are echoed through the literature on this subject: i) that not all cultural heritage can be retained in its current state; ii) that decisions must be taken on the basis of sound evidence; iii) to work with nature and to value what has evolved naturally and weathered over time and therefore not to attempt to reverse the process (2007). An interesting point not made elsewhere is that there is a need to recognise that a large number of historic buildings and structures have survived in widely differing climates and that solutions elsewhere may become relevant to us. In relation to historic buildings it is clear that the quality of the management response will dictate the success or otherwise of the climate change adaptation measures.

As the effects of climate change on the historic environment are likely to exacerbate existing processes of decay, much adaptation advice emphasises the need for regular maintenance and monitoring, as can be seen from the recommendations made to English Heritage (Cassar, 2005) which are summarised below:

**Effortless measures** - streamlining current monitoring, management and maintenance practices to enhance the stability of the historic environment. Effecting minor repairs more regularly instead of infrequent major repairs. Shifting management strategies in favour of inspection, more rigorous and more frequent maintenance and monitoring of the physical fabric.

**Local response** - extreme weather impacts are spread regionally or locally. Decisions on disaster preparedness and emergency response should be taken at regional or local level. Co-ordination with regional and local emergency services, and flooding agencies is critical, as well as local cross-disciplinary training programmes on basic preventive maintenance.

**Preventive maintenance** - keeping rainwater goods and drains clear, routine maintenance to roofs, guttering and masonry joins.

**Emergency preparedness** - with intense rain events often accompanied by strong winds, the ability to put in place emergency protection of storm damaged property can reduce the risk of further damage (e.g. heavy duty tarpaulins, sand bagging etc).

**Being realistic** - we must re-evaluate the 'save-all' approach to the historic environment. A balanced assessment of what to conserve and why is needed, including an assessment of the value and significance of every day elements or the commonplace.

**Adaptation** - modifying drainage and rainwater goods in historic buildings, and the discrete provision of irrigation and water storage in parks and gardens. (Taken from Cassar 2005 and CBA website on climate change)

### 6.7.2 Negative impacts of general adaptive responses on cultural heritage

In relation to coastal sites and inland waterways there are a number of ways that large-scale adaptive responses to coastal erosion or flooding can have a detrimental effect on the cultural heritage in these areas (Heyworth and Chitty 2008, English Heritage 2006, Edwards and O'Sullivan 2007). New flood defences in historic towns can cause major damage to the archaeology of historic water fronts, as well as to the character of historic quaysides and waterside buildings (English Heritage, 2006). This is very relevant in Ireland given the number of towns and cities that are vulnerable to rising sea levels. New, more effective rainwater disposal systems may damage the historic integrity of some historic buildings (English Heritage, 2006). Hard coastal defences can damage existing historic structures, and cause erosion of unprotected sites at other spots in the coastal neighbourhood. However, soft engineering options such as managed alignment also present a risk to archaeology, and historic buildings on the coast. The abandonment of land to coastal flooding or erosion, can lead to the loss of archaeological sites and historic structures. The creation of new wet land habitats along the coast or riverine areas, or the extension of coastal habitats inland such as saltmarshes or mudflats may lead to conflict or differing priorities between cultural and natural heritage (Edwards and O'Sullivan 2007, Historic Scotland 2007).

### 6.7.3 Prioritising what to save

This brings us to the point made by all the following organisations - UNESCO, ICOMOS, Noah's Ark, Historic Scotland, NT, EH - that it is not possible to save everything; hard decisions must be taken based on good information taking into account rarity, historic importance, and importantly the value placed on a site by local communities, a point emphasised by ICOMOS (2008) and UNESCO (2008). Likely coastal processes and the value of natural resources should also be taken into account. In Ireland, this approach may be difficult to communicate clearly. The widely held attitude of 'hold the line' at any cost (Devoy, 2008) has resulted, and continues to result, in the installation of hard coastal defences to protect particular features with no consideration of the long-term impacts on the coasts, or knowledge of coastal processes or even, in some cases with any consultation with the relevant government departments. Resources are allocated to such projects based on the desires of local communities often communicated through their local TDs (Edwards and O'Sullivan, 2007), This may result in the protection of one site to the detriment of another elsewhere in the coastal vicinity. While community values are important and must be taken into account, decisions on what to save or not must also be founded on an informed assessment of the cultural heritage resource.

### 6.7.4 Vulnerability mapping

Vulnerability mapping has been proposed as a tool for assessing on what should or should not be saved (Noah's Ark 2007, Cassar 2005). Cassar (2005) included a series of demonstration maps to show the usefulness of GIS overlays including temperature change, heritage sites, soil susceptibility, reduced spring, summer, and autumn rainfall, extreme rain in winter, coastal flooding and loss, and flood risk. This type of mapping could be carried out in Ireland based on regional climate change models and existing data sets. However these models would still be at a coarse scale. According to Noah's Ark, climate change risk assessment requires detailed knowledge of the cultural heritage exposed to possible climate change hazards such as the geographic location of relevant climate hazards and impacts based on knowledge of local geology, hydrology, soil type, slope, etc. The overlapping of climate hazard maps and cultural heritage maps should allow the identification of areas at risk. However, as they point out, this level of information is rarely available so cultural heritage managers need to find a short cut. Edwards and O'Sullivan (2007) have already suggested a methodology to assess vulnerability of coastal archaeology based on palaeographic models which have been discussed earlier in this chapter. The current internal risk management procedures used by Waterways Ireland may offer useful tools for the inland waterways cultural sites.

UNESCO has a methodology of vulnerability assessment for World Heritage Sites, the principles of which can be applied to all aspects of heritage (UNESCO, 2007). One has been carried out for Bru na Boinne which highlights the information gaps and gaps in heritage management in Ireland (Daly, 2008). The rock art, megalithic tombs, and cultural landscape were assessed for their vulnerability from changes in temperature, wind and rainfall as presented in the ICARUS climate change scenarios for Ireland. The potential impacts include increased biological and chemical, thermoclaustic and mechanical weathering of the rock art, flooding and structural damage of the tombs including collapse due to landslides and subsidence. The cultural landscape may be affected by reduction in the water table, changes to biodiversity and agricultural practices, as well as landslides. The author, Cathy Daly, collated this data in consultation with key stakeholders who also supplied her with information. In her opinion the lack of data limits the selection of suitable indicators to measure change which underlines the 'urgent need for research and monitoring as a first step.' Better understanding of the sensitivity and exposure of the site to climate change will allow appropriate adaptation measures to be put

in place. An overall long-term conservation plan would provide the overall structure for the environmental monitoring required, the actions to be taken based on its results, and allow for stakeholder involvement. Daly also recommends a site-specific disaster plan, in particular, given the increased risks from flooding and extreme weather events likely in the near future (Daly, 2008).

The National Trust have carried out a vulnerability assessment on three of their coastal sites in Northern Ireland referred to earlier in this chapter (NT 2007b). Short, medium and long term scenarios are made for the Giant's Causeway World Heritage Site, North-East Strangford Lough and Murlough National Nature Reserve, which the Trust will use in planning the future, in partnership with local communities and others. The National Trust outlines its principles of adaptation: i) long term planning, ii) working with natural processes as far as possible rather than resorting to hard engineering works, iii) thinking within a wider context, iv) working in partnerships to find solutions and v) involving the public. These principles should be kept in mind for any climate change planning strategies in Ireland.

It can be deduced from these examples that more baseline information and a greater level of management of sites and the cultural resource will be required in Ireland to inform monitoring programmes and successful adaptation measures for the cultural heritage of our coastal and inland waterways.

#### 6.7.5 Impacts of mitigation measures on cultural heritage

Mitigation, that is attempts to reduce the quantity of greenhouse gases in the atmosphere (IPCC, 2004), will also affect cultural heritage. The production of renewable energy from hydroelectricity, biofuel production and wind (land and off-shore) will impact on current landscape character while measures to ensure energy efficiencies may impact significantly on historic buildings (Heyworth and Chitty, 2008). As the Noah's Ark project points out: 'Our perception of how we expect cultural heritage to look may well have to change' (2007). In Ireland, there is high potential for landscape and seascape change particularly in remoter areas due to energy generation off-shore and the development of associated energy grid infrastructure. Nevertheless, cultural heritage may be able to play an active role in mitigation generally. For example, historic mixed-use towns are more pedestrian-friendly, or can be made so, and therefore, promote sustainable transport (Historic Scotland, 2007). Inland waterways may provide an important element in assisting in flood alleviation plans, drawing water away from vulnerable areas, and in helping cleaner transport for freight, and also along the towpaths on foot and on bicycles. IWAC (2007b, 2008) suggests that waterways should be given a role to play in adaptation and mitigation measures, possibly offering storage facilities or as transporters of water, or as part of flood defence systems. The opportunity of using Irish waterways for transport should be re-examined. In the UK, Freight by Water, an independent group is promoting successfully freight transport by sea and inland waterways. The River Severn and Sharpness Canal have been re-opened for the transport of aggregates (British Waterways, 2009). British Waterways is also promoting the use of hydropower to generate electricity on its waterway system (British Waterways, 2008). The use of canal towpaths as part of sustainable transport routes is another positive contribution that waterways can play in mitigating against the impacts of climate change.

#### 6.7.6 Adaptation on inland waterways and on coastal heritage

Noah's Ark (2007) offers useful advice on basic strategies against climate change effects on historic structures, which can be applied to historic structures along Ireland's inland waterways and along the coast.

- Regular inspection of structural strength
- Regular maintenance of structures
- Long-term monitoring of structural strength
- Installation of warning systems - in particular, for flooding

In relation to historic bridges, they emphasise the need to remove floating objects in the water that accumulate in front of bridges or other barriers, creating dams that increase water pressure, and could in certain cases, cause the water level to rise. Cranes were used to move objects from the water to put on land, on the historic Charles Bridge in Prague in 2002.

It is clear that it will be necessary to decide whether to accept certain losses to Ireland's coastal cultural heritage and to manage the loss by recording the threatened sites or whether to re-locate items of heritage away from their vulnerable location. Long-term planning for sites located on soft, vulnerable coastlines where managed realignment may be the most appropriate tool for coastal 'protection' will also be necessary (Noah's Ark, 2007). The experience of Historic Scotland is illuminating: according to Historic Scotland (2007) building coastal defences is too expensive and 'ultimately futile'. Managed realignment, as advocated by other agencies like Scottish Natural Heritage, is not suitable for historic environment assets due to their fixed nature. In the opinion of His-

toric Scotland, the most feasible option is to survey as much of Scotland's coast line as possible. Once this is done, significant sites must be surveyed in detail. But at time of writing (2007), significant sites were being identified and washed away faster than they can be dealt with at current levels of resource (Historic Scotland 2007).

#### 6.7.7 Research

Research themes emerge from the literature (Noah's Ark, 2007, Cassar, 2005,2008, UNESCO, 2008, Sabbioni, 2008)

- The need for good quality baseline information
- A hierarchy of priorities for allocating resources, as not everything can be saved, or can be saved unaltered
- The need to monitor the changes that are occurring to understand sensitivities to climate impacts and the mechanisms of change
- Prediction technology - so that the effects of extreme events like floods can be mitigated for
- To explore the impact of SLR on cultural heritage protection
- The need to examine the processes of decay and deterioration of heritage materials
- Disaster preparedness - vulnerability assessments, risk management and training.

Policies and strategies on climate change impacts must be based on research (Cassar, 2008) and this in turn will influence training programmes for heritage managers, as well as awareness raising programmes aimed at practitioners and the general public. While there are still large gaps in information, short-term interim guidance is needed.

UNESCO stresses the need to understand the impacts of climate change on society and the effects on relations between communities and their heritage. Cassar (2008) reiterates this by stating that the heritage sector should be aware of public perceptions and the value the public give to the preservation of the historic environment. In Ireland we will need to challenge and change public perceptions regarding appropriate responses to climate change.

#### 6.8 Conclusions

As a first step, we need to gather baseline data on our coastal and inland cultural heritage resource, in particular the coastal resource in the light of SLR. Baseline data should cover the identification of sites including their location, their state of preservation and site type. Once this is done, there is a need to:

- Conduct basic vulnerability mapping should be done using the new technologies and methodologies, as well as new data sets from INFOMAR, ICPSS, OPW flood mapping
- Set up management structures for the cultural heritage resource on a regional basis
- Carry out research on public perceptions of the visible changes taking place
- Raise awareness among the public of the processes of natural decay and the role of potential climate change impacts in exacerbating these
- Establish a framework for setting priorities on what to save or not, based on best available practice as advocated by ICOMOS, UNESCO
- Monitor changes and sensitivities of site types and specific sites to climate change
- Examine the reaction of specific materials in the cultural heritage resource
- Take part in international, EU-funded projects to increase skill base and knowledge in Ireland, as well as to access additional funding
- Improve our institutional capacity for the management of our cultural heritage in the light of climate change
- Institute disaster preparedness among heritage practitioners

While it is unlikely that resources will be available in the near future to carry out all of these actions, interim guidance should be considered and regional projects should be conducted in vulnerable areas. Some of these steps are already in process such as Waterways Ireland (WI) and their disaster preparedness; the expertise and experience of agencies like WI should be used to advise others. The inability to carry out in a comprehensive way all of the actions listed earlier should not be an excuse for taking no action at all. UNESCO recommends the application of the precautionary approach in dealing more actively with uncertainty when taking decisions in relation to World Heritage (2008). In the same way we should be inspired to provide for the potential impacts of climate change on our cultural heritage of our coasts and inland waterways.

Table 6.3 Summary of impacts on cultural heritage of Ireland's coast and inland waterways

	Temperature	Precipitation and altered hydrological regime	Sea level rise and storm surges, Increased storminess and wind	Adaptation
INLAND WATERWAYS				
	<p>Freeze-thaw/frost damage</p> <p>Depletion of oxygen in water, accelerating microbial decomposition of organic materials e.g. in crannog sites, or water logged sites.</p> <p>Biochemical deterioration</p> <p>Biological attack of organic materials by insects, moulds, fungi invasive species like termites. May affect wooden lock equipment</p>	<p>Increased river flow causes erosion of inorganic and organic materials e.g. historic bridge footings. This also alters loading of historic and archaeological structures, and causes build up of flotsam .</p> <p>Damage due to faulty or inadequate water disposal systems including the navigation channels;</p> <p>Subsoil instability, ground heave and subsidence - could affect historic structures along the waterways, as well as canal banks.</p> <p>Physical changes to porous building materials due to rising damp e.g. to lock keepers cottages, and stone bridges</p> <p>Loss of archaeological data preserved in water-logged/ anaerobic/anoxic conditions</p> <p>Crystallisation and dissolution of salts caused by wetting and drying, affecting historic structures, archaeology, etc</p> <p>pH changes to buried archaeological evidence, including underwater ones</p> <p>Corrosion of metals - in historic structures, and also of historic boats.</p>	<p>Penetrative moisture into porous cultural heritage materials e.g. stone navigational structures</p> <p>Structural damage and collapse</p> <p>Deterioration of surfaces due to erosion</p>	<p>Raise public awareness of natural flooding and river erosion processes and why hard interventions may not work</p> <p>Vulnerability mapping of inland waterways - water supply and features at risk</p> <p>Set up system for identification and recording of sites in vulnerable areas.</p> <p>Framework for deciding what or what not to save</p> <p>Set up monitoring and management structures for sites</p> <p>Emergency preparedness, and climate change awareness training</p>
underwater			Wrecks and underwater landscapes threatened by exposure/damage	
Indirect effects	<p>Invasive species proliferate; Increases in mould growth; decline of original plant material</p> <p>Results in changes in the natural heritage values of cultural heritage sites and changes in the appearance of landscapes</p>	<p>Inappropriate adaptation to allow historic structures to remain in use - destroying historic character</p> <p>Inappropriate flood defence systems impact on historic features and urban landscapes</p>		



	Temperature	Precipitation and altered hydrological regime	Sea level rise and storm surges, Increased storminess and wind	Adaptation
COASTAL AREAS				
Land-based and intertidal	<p>Freeze-thaw/frost damage</p> <p>Depletion of oxygen in water, accelerating microbial decomposition of organic materials particularly in intertidal sites, e.g. in estuaries</p> <p>Biochemical deterioration</p>	<p>Erosion of inorganic and organic materials due to flood waters</p> <p>Damage due to faulty or inadequate water disposal systems on historic structures e.g. Martello towers</p> <p>Subsoil instability, ground heave and subsidence - could affect historic structures along the coast on rocky shores as well as in softer shore lines</p> <p>Corrosion of metals - in historic structure especially 19th and 20th century coastal fortifications, industrial and communications structures, and also of historic boats.</p>	<p>Coastal erosion causing structural damage, collapse and removal of sites on soft coastlines, or vulnerable rocky shores.</p> <p>Coastal fortifications, industrial and communications sites are at particular risk. Archaeological sites on softer shorelines also high risk.</p> <p>Penetrative moisture into porous cultural heritage materials e.g. stone structures and monuments</p> <p>Dynamic loading of historic piers and other harbour structures during storms. Deterioration of surfaces due to erosion</p> <p>Crystallisation and dissolution of salts caused by wetting and drying, affecting historic structures, archaeology, etc</p> <p>Intertidal wrecks vulnerable to exposure and being broken up by storm energy or humans</p>	<p>Raise public awareness of natural coastal processes and why hard interventions may not work</p> <p>Vulnerability mapping of coast line</p> <p>Set up system for identification and recording of sites in vulnerable areas.</p> <p>Framework for deciding what or what not to save</p> <p>Set up monitoring and management structures for sites</p> <p>Emergency preparedness, and climate change awareness training</p>
underwater	Corrosion of metals - wrecks as pH of sea waters changes		Wrecks and underwater landscapes threatened by exposure/damage	
indirect			Inappropriate coastal defences cause erosion elsewhere on coast, damaging more heritage sites. Removal of sites during construction and removal of historic character.	

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Karl Brady, Underwater Archaeological Unit of DEHLG  
Colin Becker, Inland Waterways Association of Ireland, and Inland Waterways Committee of the HC  
Brian Cassells, Inland Waterways Association of Ireland, and Inland Waterways Committee of the HC  
Gabriel Cooney, Heritage Council and UCD  
John Edwards, Inland Waterways Advisory Council (UK)  
Aileen Doyle, DEHLG  
Ian Doyle, Heritage Council  
Eileen McKeever, Environment Agency  
John McKeown, Waterways Ireland Eastern Region Manager  
Niall McManus (PGEO), consultant geologist  
Glen Millar, British Waterways  
Colin Murray, Heritage Council  
Paula Treacy, Waterways Ireland

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## Chapter 7. IMPLICATIONS FOR TOURISM AND AMENITY IN IRELAND

Authors: Craig Bullock (Optimize), Mary Stack and Paddy Mathews (Fáilte Ireland).

### 7.1 Introduction

Tourism is a significant contributor to the Irish economy, both domestically and as a major source of foreign earnings. The sector depends heavily on the natural and cultural heritage that underpins a wide range of tourist and amenity activities. This same heritage contributes enormously to our quality of life, from social interaction to the health benefits that can be derived from being outdoors interacting with our heritage.

This chapter draws on the potential heritage impacts that are set out in earlier chapters and attempts to anticipate what these impacts will mean for tourism<sup>8</sup>. In setting out these impacts, it is proposed to group them under two main headings which reflect the ways in which climate change can impact on tourism:

- i. impacts on the attractiveness of Ireland as a holiday destination, and
- ii. impacts on visitor enjoyment of their holiday through the range and quality of tourist activities provided.

The chapter focuses solely on the implications to tourism from the physical impacts on our heritage that are likely to result from climate change. It deals only briefly with impacts that may arise from future adaptive measures that may be introduced by Government.

Wall (1998)<sup>9</sup> has argued that the more remote destinations and those relying on natural resources would be more vulnerable to climate change. Ireland as a destination for overseas tourists matches both of these descriptions. While the prospect of warmer, drier summers may have a positive impact on the attractiveness of Ireland as a holiday destination, the predicted increase in the severity and frequency of storms may have implications for the usability and quality of certain tourist attractions and facilities. At this point in time, when we are just beginning to create models for climate change in Ireland and are beginning to witness the first signs of climate change both in Ireland and globally, we can be certain of two things:

- (i) that the precise implications of climate change for tourism are difficult to predict, as are the implications of climate-related impacts; and
- (ii) that tourists are better able to adapt to changing climatic conditions than the tourism industry (Nicholas & Amelung, 2006), meaning that tourists will quickly switch their choice of destination if the results of climate change begin to impact negatively on the enjoyment of their holiday.

Preceding chapters have highlighted the range and type of impacts that climate change is likely to have on Ireland's inland waterways and coastal/marine environments. In order to better understand the tourism implications of the above, this chapter examines how climate change events such as sea level rise, changes in temperature and precipitation and storm surges will impact on tourism activities such as angling, cruising, golf, nature tourism, and island tourism. Where possible, examples have been provided of how specific tourist amenities are likely to be affected.

Steps that will be necessary in order to respond and adapt to the predicted impacts are outlined later in this chapter. It is intended that these recommendations for adaptation would be used to inform the strategies and policies employed by all stakeholders in the tourism industry, from national, regional, and local authorities to the tourism providers themselves.

### 7.2 The economic value of tourism

#### 7.2.1 General<sup>10</sup>

In 2007, visitor numbers to Ireland rose to a record 7.8 million, an increase of 5% on 2006 figures. Tourism revenue also increased over the same period, with 2007 returning a total of €6.5 billion. Irish tourism revenues declined marginally in 2008 to €6.3 bil-

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<sup>8</sup> This chapter is to be read in conjunction with Chapters 5 and 6 of this report.

<sup>9</sup> Quoted by Nicholls & Amelung (2006).

<sup>10</sup> All figures in this section are taken from the Fáilte Ireland website ([www.failteireland.ie](http://www.failteireland.ie))

lion (down 2%) as a consequence of the first decline in overseas visitor numbers in seven years and the lack of growth in domestic expenditure for the first time in five years.

Tourism can be considered to be an important indigenous industry, accounting for almost 4% of GNP annually. The value of tourism to the economy is all the more important in that the tourism and hospitality industry is labour intensive, supporting approximately 322,000 jobs (Fáilte Ireland, 2007). It also depends on a diverse supporting network of suppliers, causing the direct benefits to be multiplied through the sector's spending on inputs and employment.

The quality of sightseeing in Ireland and our reputation for a clean, unspoilt environment have always been major draws for international tourists. Sightseeing is still the major activity, but outdoor pursuits represent the main activities for 6% of foreign visitors, while walking and rambling are estimated to account for 20% of the activities enjoyed by domestic tourists (Fáilte Ireland, VAS, 2006).

**Table 7.1 Importance of factors in considering Ireland for a holiday (Fáilte Ireland VAS, 2007).**

	2002	2003	2004	2005	2006	2007
	%	%	%	%	%	%
<i>Friendliness/Hospitality/Pace of Life</i>						
<i>Friendly, hospitable people</i>	87	86	85	84	83	81
<i>Easy, relaxed pace of life</i>	74	71	69	71	68	62
<i>Environment</i>						
<i>Beautiful scenery</i>	86	85	83	82	80	80
<i>Natural, unspoilt environment</i>	81	80	77	77	74	71
<i>Attractive cities/towns</i>	64	63	63	60	58	54
<i>* Good range of natural attractions</i>	n/a	n/a	n/a	n/a	69	66
<i>* Good combination urban/rural experiences</i>	n/a	n/a	n/a	n/a	45	48
<i>Value/Price</i>						
<i>Good all round value for money</i>	63	62	62	59	57	55
<i>Competitively priced air and sea fares</i>	45	45	55	54	54	40
<i>Reasonably priced accommodation</i>	62	61	62	60	59	52

\* New in 2006

The same visitor attitude survey (VAS) revealed criticism of the cost and ease of access, litter and pollution, and value for money. If tourism is going to be adversely affected by climate change, it is all the more important that the fundamental product is of high quality.

The Fáilte Ireland Tourism Product Development Strategy 2007-2013 has identified various priorities to support sustained regional growth. These include recommendations for improvements in infrastructure, as well as the promotion of a range of tourism experiences and the maintenance of a high quality environment.

### 7.2.2 The economic contribution of water-based tourism and recreation

The Marine Institute published a report in 2004 entitled *A National Survey of Water-based Leisure Activities in Ireland* which assessed the economic contribution of domestic water based tourism to the Irish economy in the previous year (2003).

This survey indicated that around half of the adult Irish population were involved in some form of water-based recreation or leisure in 2003. It estimated that combined expenditure of €434 million per year (for the year 2003), equivalent to 45% of total domestic tourism revenue (at that time), supported 5,100 jobs (directly and indirectly full-time equivalent). In addition, the contribution of overseas visitors to water-based tourism was put at €132 million, supporting a further 3,100 jobs. Key activities include sailing, cruising, coastal activity recreation (e.g. surfing, kite surfing, diving), angling/sea angling, and general water-related leisure, each of which are discussed later in this chapter.

While participation in sailing and active water sports has grown in recent years, participation in some other areas has been static. Indeed, the number of people who reported going swimming in lakes or in the sea has declined. Many respondents to the Marine Institute survey commented that they would participate more if facilities were improved. Pollution was also raised as a concern by many respondents, especially anglers and surfers.

*Table 7.2 Economic benefits of domestic water-based tourism (Marine Institute, 2004).*

	<i>participants</i>	<i>expenditure</i>	<i>employment</i>
<b>Trips to beach or swimming</b>	1,488,000	€277 million	3,200
<b>Sea and freshwater angling</b>	218,000	€59 million	730
<b>Coastal and inland boating</b>	142,800	€50 million	660
<b>Other water-sports *</b>	53,400	€35 million	480
<b>Nature-related tourism</b>	65,500	€6.6 million	
<b>Visits to islands</b>	33,200	€5.8 million	

\* water ski, jet ski, surfing, sail boarding, diving, other sea sports

More recently the Irish Marine Federation published a report entitled *The Potential for Growing Marine Leisure, Irish Sea Marine Sector Marketing and Business Development Programme* (O'Driscoll *et al.*, 2007). This confirmed the rapid growth in marine tourism which it valued at €566 million alone (including overseas as well as the domestic market). Boat sales have continued to grow at a rapid rate.

Much faith has been placed in the capacity of the marine and water sector to deliver regional tourism growth and economic diversification, for example in relation to former fishing ports. State investment of £130 million (€165 million) was proposed at the beginning of the former National Development Plan (NDP) (2000-2006). It is proposed that this would be supported by a comparable level of private sector investment. Public investment has assisted the provision of coastal marinas and improved navigation facilities for inland waterways and physical links between river systems such as the Shannon and the Erne.

Water based activity also features strongly in the Fáilte Ireland Tourism Product Development Strategy 2007-2013, which calls for further additional spending under the new NDP, including spending on moorings, jetties, water sports centres, and walking or cycling routes.

The following sections of this chapter deal with the likely implications of climate change for (i) Ireland's image as a destination and (ii) visitor enjoyment of their holiday and the range and quality of tourist activities. For the purpose of this chapter the predicted impacts relating to marine areas and those relating to inland waterways have been grouped together, where appropriate, under the heading of a particular type of tourist activity that is likely to be affected.

### 7.3 General impacts of climate change on Ireland's image as a tourism destination

#### 7.3.1 Visitor numbers/ patterns

At a general level, models have developed to demonstrate how tourist numbers and patterns could respond to climate change. A Tourism Climate Index has been developed by Mieczkowski (1985) and includes data for comfort (i.e. temperature and humidity), precipitation, sunshine and wind. This index has been employed by Nicholls and Amelung (2006) to predict changes in tourism activity, namely tourist numbers and the seasonal and spatial distribution of tourists in north-west Europe based on two IPCC scenarios of moderate and high emissions, with respective levels of climate change.<sup>11</sup> Their analysis suggests that north-west Europe could acquire a new comparative advantage for tourism as Mediterranean destinations become too hot to be comfortable for tourists during the summer. Traditionally, 'sun, sea and sand' has been a primary motivation for holidays in southern Europe, but as the climate 'improves' in north-west Europe, more of these tourists are likely to holiday at home. In addition, as the century progresses and climate change becomes more established, these stay-at-home tourists are likely to be joined by higher tourist arrivals from southern Europe. As Arkell *et al.* (2007) observe, these changing flows could have profound implications for northern Europe given that an estimated 100 million tourists visit the Mediterranean each year, spending around 100 billion dollars (Mather & Viner, 2006)

<sup>11</sup> Note that the paper predates the IPCC Fourth Assessment Report published in 2007 although the changes predicted are of the same direction.



Changes in Ireland's climate, and therefore its 'comfort index' for tourism, are moderated by the oceanic effect compared with continental Europe. Consequently, the Nicholls and Amelung analysis suggests little change for the next ten years, but predicts that, by the 2020s, Ireland will be enjoying two months of 'pleasant' climatic conditions under a moderate emissions scenario, with 'good' conditions prevailing in the south east. By 2080, all of Ireland is predicted to experience two such 'good' months.

The terms 'pleasant' and 'good' are, of course, qualitative descriptions used for comparison with the climate in other parts of Europe. 'Good', as defined by the Tourism Climate Index, should not be interpreted as implying little change on what we, in Ireland, might regard a reasonable summer. Rather, the index suggests warmer, drier conditions across north-west Europe, extending also into the spring and, especially, the autumn months. Nicholls and Amelung note that tourists are better able to adapt to changing climatic conditions than the tourism industry, especially now that cheap airfares and short breaks are widely available. In order to make maximum gains from the predicted changes, the tourism industry in Ireland will have to respond to the predicted changes.

Nicholls and Amelung also note that little research has been conducted on tourist attitudes, but of that which is available they note that extreme events, such as summer heat waves, can have a significant influence on holiday plans. Indeed, there have been few studies which have combined the relative pull of weather and the effect on tourist attractions. One initial study by Hamilton and Tol (2006) provides an econometric model that includes variables known to influence tourist behaviour along with climatic variables. Overall, these models predict that many Irish nationals will be inclined to stay at home in the future while the numbers of foreign visitors, particularly from southern Europe, could increase. As well as the direct impact of climate change, these changes in tourist numbers will bring their own problems in terms of demands for waste water infrastructure, water supply and power (with subsequent implications for carbon emissions). There will be a potential risk of over-development in certain popular tourist destinations, exacerbated by the present liberal planning regime. This could result in pressure on the environment and, in particular, water quality due to possible increases in waste discharges combined with reduced rainfall during the summer months and higher temperatures.

Infrastructure constraints have already posed limitations on tourism development in seaside towns like Enniscrone, County Sligo, and Tramore, County Waterford. Where basic infrastructural capacities are exceeded, environmental problems can result, evidenced by the loss of Blue Flag status at beaches when water quality standards have not been achieved.

McEvoy *et al.* (2007) caution against placing too much emphasis or consideration on the influence of climate on tourism patterns. In the first instance, they draw a distinction between tourism and recreation, on the basis that the former is more determined by pre-planning, while recreation is more spontaneous and weather dependent. This distinction is emphasised by the observation that recreation is a key component of domestic tourist activity.

Furthermore, weather has not traditionally been a determinant of visits to Ireland. For example, Ireland's mild climate was cited by only 13% of French visitors as representing a positive factor that distinguishes Ireland from other destinations (VAS 2006, Fáilte Ireland). On the other hand, while our climate is not a notable determining factor in choosing Ireland as a destination, weather can impact on a visitor's satisfaction once they are here. Ireland's unpredictable and changeable weather was cited as a disadvantage by 15% of overseas visitors (VAS 2006, Fáilte Ireland), a figure that increased to 19% in 2007 due presumably to the particularly wet summer of that year.

McEvoy *et al.* add that tourism managers anticipating a bonanza due to warmer temperatures would be better advised to direct their attention to improving the marketing of their product. Socio-economic factors have influenced trends in tourist behaviour, as illustrated by the growing interest in nature tourism, or the influence of rising incomes and an ageing population on the popularity of short breaks.

### 7.3.2 Landscape

The annual Fáilte Ireland Visitor Attitude Survey (VAS) consistently confirms that people and landscape are the two factors that exert the greatest lure for visitors to Ireland. Table 7.1 reveals that 80% of international visitors in 2007 rated scenery as an important reason for their trip to Ireland (the second highest category after the Irish people). Over one quarter of visitors rated scenery as a factor that distinguishes Ireland from other destinations. However, research undertaken in November 2008, indicates that overseas visitors have certain preconceptions about the character of Ireland's landscape. The majority of overseas visitors strongly associate rolling hills, greenness and open countryside with Ireland, but the research shows that their knowledge of the detail of what our landscape has to offer is extremely limited. Furthermore, overseas visitors in general do not associate Ireland with boglands and peatlands, forest parks or coastal landscapes and cliffs. Therefore any impact from climate change on Ireland's undulating farmland, greenness and open countryside would have a proportionately more harmful impact on visitors' perceptions of Ireland.

The value of Ireland's landscape to tourism stretches beyond its visual qualities for the visitor. Landscape also has both a tangible and intangible influence on Ireland's culture, be this music, literature or film (see Sweeney *et al.*, 2008). Much of Ireland's most well-known literature, such as the poetry of Yeats and Heaney and the novels of Joyce and McGahern, is inseparable from the rural and urban landscapes that influenced it. It is important that to retain the value of these landscapes to tourism, that their essential character is maintained.

The greenness and lushness of Ireland's landscape, resulting from the dominance of grass and arable crops as the primary land cover, is the primary contributor to the distinctive character of Ireland's landscape. Sweeney *et al.* (2008) conclude that while climate change is unlikely to eliminate the dominance of grass in the Irish landscape during this century, it will begin to threaten the productivity of grasses during the dry summer months. Summers like that of 1995 during which the grass turned brown, are likely to occur more frequently, particularly in the south-east. In addition to the colour change which would occur to the landscape, this may see cattle removed from the fields during the height of the summer months in some areas, resulting in the requirement for shelter and silage supplements (Sweeney *et al.*, 2008).

Inevitably, though, the character of Ireland's landscape will change in response to climate change. Such change is acknowledged by the Government's *National Spatial Strategy* (2002) which accepts that change will not be confined only to landscapes that have been designated for special protection. As with most landscape change, the changes will be gradual and, as such, subtle, as perceived by each generation. Drier summers will reduce the lushness of the landscape, possibly eliminating many smaller wetlands and pockets of damper ground occupied by rushes or the familiar yellow flag iris.

It is our coastal landscapes, however, that appear to be most at risk from transformation from climate change. While hard coastal areas will be resilient from the rising sea levels and coastal erosion, leaving important tourist attractions such as the Cliffs of Moher and Slieve League unchanged, soft coastal areas will be particularly vulnerable (Sweeney *et al.*, 2008). Sea level rise is already accelerating coastal erosion along the western sea board and along parts of the south and south-west coast. Sweeney *et al.* (2008) predict that the: 'soft boulder clay coasts of south Counties Down, Louth, Dublin, Wicklow and Wexford are where retreat is occurring fastest. In extreme cases, erosion rates are exceeding 3m (10ft) per year. Even in the west and south, however, low-lying bays and estuaries - such as Tralee Bay, Cork Harbour, Clew Bay and especially the Shannon Estuary - are vulnerable to increased flooding as sea level rises. The worst-case scenarios of a storm surge occurring in conjunction with a spring tide give a 50:50 chance that 50 km<sup>2</sup> (116 miles<sup>2</sup>) could be flooded at some stage over the coming century'.

Overall, much of the traditional appeal of the Irish landscape for tourists will be at risk, particularly for international tourists given the image they have of Ireland. However, many of these changes to our landscape will be gradual, making adaptation more feasible, and not all of the predicted changes will necessarily result in changes to the visual appearance of our landscape.

In terms of the overall impact from these changes to our landscape, McEvoy *et al.* (2007) argue that habitual behaviour is likely to ensure that tourists continue to arrive at popular locations despite the changing landscape. As climate change progresses, foreign visitors will become conscious of climate induced changes in the countryside in their home countries and are likely to be disappointed, but not surprised by similar changes occurring in Ireland.

It is important to bear in mind that any changes to the Irish landscape rendered by climate change must be viewed in the context of other factors of landscape change, such as planning policy, settlement patterns and agricultural policy. However, some of the changes in agricultural policy will be prompted directly by issues surrounding climate change, particularly in an effort to reduce our dependency as a nation on fossil fuels. According to Sweeney *et al.* (2008), it is likely that the rural landscape will increasingly be characterised by fields devoted to biofuel production - most likely oilseed rape, elephant grass, and short rotation forestry.

## 7.4 Impacts on the visitor's enjoyment of their holiday through the range and quality of tourist activities

### 7.4.1 Cultural tourism

Cultural heritage along the coast or associated with the inland waterways of Ireland will be affected by climate change in a number of ways as identified in Chapter 6. Many of the cultural heritage features referred to in Chapter 6 are key tourist attractions. Of particular interest are the well-known sites of castles, promontory or hill top forts and tomb complexes along the coast and inland waterways.

The character of the landscape is a key element of the attraction of the many ecclesiastical sites along inland waterways such as the Shannon from Lough Derg past Clonmacnoise, Lough Ree and up to Lough Key. The landscapes that we associate with such sites are very much a part of the experience of visiting cultural heritage even though the landscape character at the start of the twenty-first century could be quite different from what it was when these monuments were built.

The character of the landscape and the cultural heritage attractions are important elements of any visitors experience of Ireland's coastline and inland waterways. As noted in Chapter 6, Ireland's coast is rich in historical sites by virtue of the role of the sea for exchange, migration and invasion. In most cases, these structures have a defensive role and were solidly built both to withstand attack and the elements. Nevertheless, as numerous structures are located directly along the coast, their foundations are vulnerable to the gradual erosion associated with rising sea levels such that damage and collapse could occur even though the structures are inherently strong.

While areas of hard coast and cliffs might be resilient against increased coastal erosion and more frequent and violent storms, the same cannot always be said of the range of cultural heritage remains that sit along this coast. Amongst historical sites at risk and of value for tourism, are Dunlough Castle in County Cork which stands above 300ft cliffs, the promontory fort of Dun Doocaher (the Black Fort) on Aran, and Dun an Oír in Kerry. Watch towers on Inishbofin in County Mayo are currently being reinforced against coastal erosion. Clearly, storms that are likely to increase in frequency and intensity present a problem for such structures, especially where they have been built on the edge of cliffs. Likewise in soft coastal areas, rising sea levels could inundate the foundations of some fortifications such as Carrigahowley Castle on the shores of Clew Bay.

Several coastal gardens are also vulnerable to climate change in the medium term, including those at Glengarriff, and Valencia Island. Subtropical plants could, of course, benefit from warmer temperatures, but maintenance and moisture demands would arise due to uncharacteristically drier summers. In this respect, coastal gardens are little different from inland sites. The principal exception would be with regard to any prospect of more storms which could inflict serious damage on some exotic plants as was clearly demonstrated by the very serious damage caused to Kew Gardens in 1987.

Stormier conditions will also have implications for managers of historic properties which are open to the public. Rising insurance and repair costs due to storm damage and flooding will increase overall running costs. Also visitor safety and access are likely to become important issues in the management of archaeological and historic sites as a result of adverse weather conditions.

In addition, increased visitor numbers will also put pressure on the conservation and management of our cultural heritage. Sustainable management policies will be required to ensure that cultural heritage assets are properly managed and that the increased visitor numbers do not undermine the asset itself.

## 7.4.2 Angling

### *General*

Participation levels by overseas visitors in angling in Ireland has increased consistently in the last number of years, increasing from 88,000 in 2003, to 128,000 in 2007 (Fáilte Ireland, Angling Facts 2007). Of this 128,000<sup>12</sup> visitors who participated in angling in 2007, 47,000 participated in coarse angling, 48,000 in game angling and 31,000 participated in sea angling. Visitors who engaged in angling while in Ireland spent an estimated €87.4 million in 2007.

### *Inland angling*

Consultation carried out as part of this review with the Regional Fisheries Boards revealed a concern about a potential impact on fish stocks given their vulnerability to changes in water temperature and river levels. Particular concerns were voiced about salmonid rivers, estuarine habitats and freshwater lakes such as Lough Conn, in County Mayo.

Chapter 5 on Natural Heritage indicates that climate change will have the following principal impacts on fish populations and angling, namely:

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<sup>12</sup> Not all visitors who fished while in Ireland stated the type of angling they engaged in.

- Changes in oceanic and riverine temperatures, its impacts on fish populations and composition, salmonids, in particular, will be at risk
- Lower summer flows may enhance water quality problems
- Spawning areas may be damaged by higher winter flood conditions
- Conditions will become more suitable for invasive/ introduced species, which will pose a threat especially during reduced dissolved oxygen periods in the summer.

The wider global characteristics of climate change will affect changes in oceanic temperatures with resultant impacts on fish population and composition. In Ireland, ocean migrating salmon and eels appear to be most at risk. In relation to salmon recovery, the efforts by the Regional Fisheries Boards to improve river management for migratory fish, combined with the recent cessation of commercial drift net fishing, could now be compromised by climate change. Salmon is amongst those species which is suspected to be most vulnerable to rises in temperature. Low river flows, if they were to occur in spring, could also interfere with up-stream migration which is typically triggered by spate conditions (Hendry & Cragg-Hine, 2003).

Salmon survival is best where seawater temperatures are between 6°C -9°C. Sea temperatures regimes are changing in the North Atlantic and North Sea, as witnessed by changes in distribution of plankton species. As detailed previously in Chapter 5, 'one-sea-winter returns' of Atlantic salmon to the Irish coast have fallen by 11% relative to 2006 and 79% relative to 1971 levels (NPWS, 2008a). While this is a result of many factors, climate change is currently perceived as one of the main threats to Atlantic salmon.

Likewise, eel populations are also believed to be vulnerable to similar changes in oceanic climate conditions, although climate change alone cannot explain the substantial fall in the returning population of eels since the early 1980s. Consultation with members of the Lough Neagh Bann Advisory Committee indicates that natural recruitment in Lough Neagh is now less than 10% its former levels.

Changes to other recreational angling species are likely to be affected by changes in lake and river conditions. As noted in Chapter 5, heavy rainfall events can lead to bank erosion and turbidity with consequences for the release of pollutants from the riverbed or banks, losses of invertebrates and the simple difficulty presented to fish which need to locate prey species. In the UK, the Environment Agency (2006) believes higher winter rainfall could wash out some spawning by brown trout. Spawning beds could also be suffocated by siltration following the effect of higher winter rainfall on erosion. Similar risks are presented for Northern Ireland where it has been noted that frequent or untimely rainfall episodes (of the type predicted by climate change scenarios) could have significant implications for salmonid migration (Arkell *et al.*, 2007).

Another serious threat arises from the effect of higher freshwater temperatures combined with pollution. Pollan could fare badly from higher winter temperatures (Harrod *et al.*, 2003, quoted in Arkell *et al.*, 2007). Warm summer weather and low flows will worsen pollution impacts, notably those arising from non-point discharges of sewage or slurry. The resulting eutrophication occurs where the growth of algae is boosted leading to a subsequent loss of the dissolved oxygen available to other aquatic species as the algae decays. Although eutrophication is already a problem in many rivers, it could be aggravated by reduced summer river flows due to higher temperatures and greater demands on abstraction. Insectivorous fish, such as salmon and trout, will be highly vulnerable.

Fitzsimons and Igoe (2004) contend that Ireland has some of the finest fish faunas in Western Europe as many freshwater communities have remained unchanged since the Ice Age. There is a large and unique genetic diversity of the native brown trout and pollan (Ferguson, 2004). Several Irish inland waters, such as Lough Corrib and Lough Mask in County Galway, and Lough Melvin in County Leitrim, are also world famous as brown trout angling destinations, attracting a substantial amount of angling tourism. Although some native species could be adversely affected, the Environment Agency (UK) speculates that in the UK, warmer summers could lead to a greater variety of fish and possibly earlier spawning. Older, larger (and more valuable from an angling perspective) fish could be better placed to survive the winter and breed. Changes to the composition of fish populations can be expected to follow from higher water temperatures.

Despite the value of the indigenous resources, it is worth noting that half of our freshwater fish species, including familiar species such as pike (*Esox lucius*) and roach (*Rutilus rutilus*), have been introduced and dispersed by humans (Went 1950; Moriarty & Fitzmaurice 2000). Introductions have provided a new angling experience at some locations, but also damaged the appeal of others. A potential threat could arise though where introduced fish species become dominant in more favourable conditions. A more im-

minent and serious threat arises from the impact of non-fish species introductions including the zebra mussel and aquatic plant introductions. The zebra mussel has been spreading across the island despite high awareness of the impact it can have on fish species through the removal of dissolved oxygen. Lough Corrib, which is renowned for its angling, is also experiencing an invasion from the African curly leaved waterweed *Lagorasiphon* which is threatening the population of aquatic insects and, therefore, trout and salmon, by cutting off the supply of sunlight.

### Sea angling

The number of sea angling operators has increased in recent years with government support for diversification from commercial fishing. Key centres for the activity include the coastal counties of Mayo, Galway, Kerry, Cork, and Louth. Boats are usually rented by groups, often higher income groups, and direct economic returns are complemented by local spending in areas that are often remote or are former fishing ports.

Climate change has been held responsible for numerous sitings of warm water species in recent years, including trigger fish (*Balistes carolinensis*) and the appropriately named sunfish (*Mola mola*) (Marine Institute, 2005). However, neither are good sport fish. By contrast, the Irish Sea Angling Federation (ISAF) comment that tuna is a popular quarry and has always been present in small numbers. They have habitually been found further out and are now being targeted by a handful of more powerful boats. However, the ISAF reports that the species is being increasingly found further inshore. However, tuna also suffers from serious overfishing, with the World Wildlife Fund (2006) warning that bluefin tuna is nearing extinction in Mediterranean and eastern Atlantic waters. As a result, the pursuit of tuna is not to be encouraged from a conservation perspective, highlighting an area where potential tourism benefits and heritage interests do not coincide.

Good weather attracts bookings for angling operators. Unpredictable weather, though, such as that experienced during the wet summer of 2007, is a deterrent. Boat owners must now pay close attention to small craft warnings given the twin considerations of rising insurance costs and tighter safety requirements.

More familiar species such as mackerel and cod (valued for their weight) are caught by shore based angling. Whereas the season for sea angling ends in September, shore fishing continues into the autumn. Autumn storms are not an issue for shore fishing as post-storm periods tend to be good for catches. Rather, the main concern expressed by the sea angling organizations consulted is over-fishing by commercial boats. Like many other coastal recreational activities, the ISAF is anxious to see an instigation of a policy of coastal zone management.

### 7.4.3 Boat use

#### Cruising on inland waterways

There has been a general decline in the number of overseas tourists cruising on inland waterways in Ireland in the past number of years. The Survey of Overseas Tourists (SOT) carried out annually by Fáilte Ireland indicates that in 2007 approximately 15,000<sup>13</sup> overseas tourists participated in inland cruising. This was down from 24,000 in 2006 and 20,000 in 2005.

Climate change is likely to have mixed implications for boating as it will for most other water-based recreational activities. Warmer, drier summers would be expected to lead to an increase in the attractiveness of cruising and boat ownership. However, this behavioural response requires that the environment is not compromised by reduced water levels or exacerbated levels of pollution.

Although improved facilities have been provided, expansion in the sector does present some issues in relation to pollution and ecology. Water quality contributes to participation, partly from an aesthetic point of view, but also because many tourists engage in angling or enjoy the surrounding wildlife associated with good water quality. As with potential increases in other tourism sectors, climate change could have indirect and cumulative effects. It will be important to ensure that any increase in participation does not lead to greater negative impacts on the environment.

Modest levels of river and canal use have been argued to be beneficial by keeping weed growth low and so supporting biodiversity (Paskell, 1979). Higher levels, though, could lead to environmental pressures such as turbidity from propellers and the effect of a minority of users travelling at excessive speed with the consequent boatwash leading to bank erosion and vegetation damage. This could increase the vulnerability of banks to flooding and other natural erosion.

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<sup>13</sup> Figures taken from the SOT are based on three-year averages.

Although warmer, drier summers should increase participation, changes in rainfall could have some direct adverse impacts. There is the risk that stretches of river could be dangerous or un-navigable in periods of drought or from higher levels of abstraction. Low water levels on shallower rivers and lakes such as the Shannon north of Athlone, the Barrow or Upper Lough Erne are thought by the Inland Waterways Association of Ireland (IWAI) to present possible future problems in relation to climate change. Problems have arisen with groundings, although Waterways Ireland report that management to date has mostly involved the erection of signage or placing of buoys near to exposed rocks. Climate change would have a further effect by increasing demands for abstraction during hot, dry periods. An integrated approach that prioritises the various demands for abstraction, taking account of navigation and heritage needs, is needed. Without an integrated approach being in place, proposals to use the Shannon to supply water to Dublin could arguably aggravate problems of low flow, particularly on the more karstic waters of Lough Ree.

Drought and evaporation could have implications for the supply of water to canals, particularly the older canals, including the Royal and Grand Canals, which are dependent on a single dominant summit source and local feeder systems. Both the Royal and Grand Canal are shallower than when commercial use prevailed and this can encourage weed or algal growth which is both unsightly and a further navigation problem. Possible adaptation options include the pumping in of water from the main rivers, assuming satisfactory supplies, or more regular dredging to increase the storage capacity of the system. Seepage is a persistent but manageable problem. However, the predominance of peat embankments in the Midlands has led to breaches following lowering of the surrounding water table due to bog workings and dry weather. Conversely, other locations have experienced serious local physical failures of embankments following a rising of the water after high rainfall. See Chapter 6 for further discussion.

Higher rainfall could also prevent river navigation at other times. Many Irish rivers, such as the Shannon, regularly burst their banks in winter, although the time of year means that there are usually no direct impacts on tourism. However, extreme rainfall events, such as occurred in the summer of 2007, can have significant impacts on navigation and subsequently tourism, as well as on agriculture and property.

Flooding in central England in July of 2007 prevented the use of rivers and canals for much of that month as well as leading to problems of canal siltration and sewage overspill. The Inland Waterways Association of Ireland (IWAI) indicate that possible locations at risk in this regard include the canal at Ballinasloe, parts of the Shannon-Erne waterway or Ardnacrusha/Limerick. Sections of the Barrow are also vulnerable.

## *Sailing and Kayaking*

### *Inland sailing and kayaking*

Although Ireland is well-endowed with lakes, inland sailing is not well-developed as a recreational activity, in part due to the proximity of much of the country to the sea. However, there are sailing clubs in Lough Neagh and on some of the larger lakes such as Lough Ree, Lough Derg and Lough Owel. Once again, warmer, drier summer weather should result in an increase in participation levels. This would be a positive development for tourism and environmental awareness. Sailors can expect to come into direct contact with water, so water quality is important. Any trend to greater pollution due to warmer or settled conditions would, of course, discourage participation.

Kayaking remains a niche activity, although the main population centres all have large clubs. Warmer summer weather will tempt more people to participate in kayaking, but unpredictable weather makes it difficult to organise sporting events, especially as Ireland currently has no dedicated course facilities. Experienced kayakers welcome higher river flows. Autumn is a popular time for kayaking and the prediction of drier autumns would be regarded as adverse development. Poor kayaking conditions have been reported from normally dependable rivers like the Boyne during the 2007 dry autumn.

Like sailors, kayakers regularly come into direct contact with the water and so would be highly conscious of any decline in water quality. Hynes and Hanley (2006) provide one of the few Irish studies on the economic value of water-based recreation, in this case for white water kayaking. They report an average consumer surplus<sup>14</sup> gain of up to €14.50 per visit from a 25% improvement in water quality. The relatively higher values that are typically placed on utility losses would suggest that the perceived cost of a deterioration in water quality could be even greater.

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<sup>14</sup> A monetary estimate of the addition to utility (or satisfaction) above the price paid or cost incurred.



### Sea sailing and sea kayaking

Climate change is likely to have a mixed impact on sailing. Once again, warmer weather could have a positive impact on participation. Interest in sailing has increased in recent years due to greater affluence, the wider availability of training and the growth in coastal adventure centres. Traditionally, a large proportion of visiting foreign boats have been from Britain, but an increasing number are arriving directly from the Continent. This is a trend that could continue as a result of climate change, due to the prospect of warmer, drier summers.

On the other hand, anecdotal evidence from consultation as part of this project suggests that winds have been less consistent in recent summers. According to IPCC (2007), there is likely to be an increase in the number of cyclones and associated strong winds, particularly during the winter over the north Atlantic. Responses to the consultation survey received from adventure centres voice anxiety over the prospect of any increase in stormy or unpredictable weather, even though the warmer conditions that are predicted could encourage more interest in water sports. The danger of unpredictable weather was highlighted by the squall that erupted suddenly in the summer of 2007 during a student racing event off Dun Laoghaire, which resulted in the capsizing of numerous boats.

### 7.4.4 Beach use / swimming

#### Lakes and rivers

Swimming has a wide participation base and naturally there is a strong correlation between warm weather and swimming. Many counties with lakes possess popular bathing areas, but only nine are officially designated as such (O'Mahony *et al.*, 2005). Even fewer have Blue Flag status and only three inland beaches (Ballycuggeran, Mountshannon, and Loughrea Lake) had Blue Flag status in 2008.

Although 84% of lakes sampled by the EPA had satisfactory water quality (EPA, 2005), widespread diffuse pollution makes it difficult to guarantee good standards. Climate change is likely to make this situation worse. More settled, warm weather conditions will allow the longer survival of coliforms from animal waste. Eutrophication and lower dissolved oxygen due to phosphate run-off will also be encouraged by higher temperatures.

In addition, an increase in invasive species could lead to possible health and safety risks to swimmers. For example, Nutalls pondweed, which has been identified in Lough Derg (LDSG, 2008), often occurs in dense stands and could present significant danger to swimmers who become entangled in it. In addition, the zebra mussel shells, also found in the River Shannon and Lough Derg could present health risk to swimmers.

#### Coastal

There is an obvious correlation between sunny weather and trips to the seaside. If predictions of warmer, sunnier weather are realised, this will certainly result in more trips to beaches and the coast. The climate data also suggests that such activity will extend later into the season too with consequent economic benefits. On the other hand, this will present considerations for beach and visitor management. Furthermore, the increased latent energy in the atmosphere provided by overall warming could lead to some wet and stormy years despite the general prediction of warmer, drier summers. Wet weather in 2007 clearly had an adverse impact on outdoor and coastal recreation, particularly in relation to domestic recreation and tourism.

As well as the effect of temperature and precipitation, the combined impact of sea level rise and storms will ultimately lead to the submergence and erosion of many popular beaches. Squeezed between promenades and built-up areas which cut off the supply of sediment to the beach system, many beaches are likely to become narrower or to remain wet throughout the day. Some could disappear entirely. Consequently, there would be fewer options for tourists to visit despite the attraction of warmer weather. Remaining beaches could become more crowded and less appealing in their own right. Recreational pressures on dunes could become worse, exacerbating already accelerated natural erosion.

Beaches, especially those in the south and west (from south of Donegal to north Wexford, refer to Chapter 4), are most likely to be especially affected as Ireland continues its gradual post-glacial rebound upwards, causing sea level rises in these areas to be relatively greater. The rate of sea level rise will often be too fast to permit compensating erosion with the result that beaches and estuaries are likely to become flooded. The locations at risk are difficult to identify, but will include shallow shelving beaches (i.e. gently sloped, and backed by dunes or soft cliffs such as those at Laytown, Curracloe, Courtown, Tramore and Ardmore), in particular those beaches where coastal defensive measures have previously been taken. Beaches backed by stone promenades or built

development are at risk from scouring or losing their drying berm and remain wet even at low tide. At Courtown, the beach is also backed by forest walks and the Office of Public Works has spent considerable sums in recent years reinforcing coastal defences. Coastal sedimentation patterns will be altered too, but in ways that are hard to predict, although research of the historical records and admiralty charts may be of assistance. Regular beach re-nourishing, as has been undertaken in Bray, could become financially impractical in the face of rising sea levels and more regular storm events.

Land ownership will add a further significant constraint on the ability of coastlines to recede as the threat to material assets is likely to be accompanied by demands for hard engineered coastal protection. As is well understood by marine engineers, hard coastal defences will have impacts on other locations along the coast. Beaches and natural habitat may fare poorly where material assets take priority.

Many seaside towns owe their existence primarily to the beach as a recreational feature and much of the tourism expenditure associated with these coastlines occurs in seaside restaurants, pubs, shops and guest houses. Many of these beaches are greatly valued by local people and visitors alike as demonstrated by concern and frustration felt over the increasing disappearance of Rossbeigh spit, albeit possibly for entirely natural reasons<sup>15</sup>. The models of tourism flows discussed at the beginning of the chapter may suggest an increase in tourism in north-west Europe, but these tourists could have fewer beach options to choose between despite the greater attraction of beaches in warm weather. Remaining tourist beaches are likely to become more crowded and, inevitably, less appealing in their own right. Where they survive, more remote beaches may be subjected to yet stronger development pressures including the provision of visitor facilities at beaches that have heretofore not been used by large numbers of people.

By comparison, hard rock cliffs are better able, by their nature, to withstand many of the impacts of climate change. However, some features of value for tourism, including such obvious examples as the Giant's Causeway or Kilkee Fossil Beds, would be impacted upon. Access by boat or kayak to the numerous caves along the Causeway Coast, or around islands such as Bere Island in County Cork or Gola in Donegal, could also be affected at the higher extremes of sea level rise.

Aside from erosion risks, a further significant problem arises from pollution risks, namely from sewage outflows, storm water outflows and diffuse pollution. Climate change would accentuate an existing problem in that investment in this infrastructure to date has been inadequate. Although new investment is being made in waste water facilities in response to the EU Bathing Water Directive, this is a gradual process given the scale of the infrastructural deficit. Inadequate waste water treatment has been an on-going issue for many years in locations such as Rathmullen, Balbriggan and Buncrana. Diffuse pollution from hydrocarbons and related pollutants is a further significant problem where adjacent areas are developed. Predictions of increased storm frequency present a problem in this regard, by washing off pollutants from hard surfaces or by stirring up of sediments offshore.

#### 7.4.5 Nature tourism

##### *Birdwatching*

Special interest birdwatching is relatively under-developed in Ireland, but it is nevertheless an important contributor to domestic tourism. It is also an activity that can be consumed by non-specialist interests, especially where supported by visitor facilities or located close to conventional tourism destinations. The economic and social benefits have been recognized across the country as, for example at Lough Neagh and Belfast Lough where visitor centres are located or, in Donegal, at Inch Lake where a heritage centre is similarly proposed. There are numerous popular coastal wetland destinations in Ireland, including Bull Island in Dublin and Kilcoole in Wicklow, both of which are significant for their amenity value. The Malahide Estuary and North Slobbs of County Wexford are more popular amongst dedicated birdwatchers, but are also valuable amenities and education centres. The geographical position of Cape Clear/Sherkin Island in West Cork, and Loop Head/Bridges of Ross in County Clare means that these sites are excellent for scoping migrating birds and rarities with the result that they attract both long stays and international visitors. Bird and seal populations at locations such as the Saltee Islands, Ireland's Eye, or Dalkey Island contribute significantly to the enjoyment people get from other specialist activities such as sailing, diving and kayaking. In Kerry, the proximity of the Skelligs to nearby gannetries means that visitors to this World Heritage Site have the added bonus of enjoying gannets plunging into the ocean to catch fish.

Warmer sea temperatures have been implicated as possible causes of breeding failure amongst cliff breeding sea birds (guillemots, razorbills, puffins) in the UK. Such locations often double as popular tourist destinations (e.g. Rathlin Island), often complementing the other attractions of nearby seaside towns and cultural heritage. Ireland is also a winter and migratory home for tens

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<sup>15</sup> Anne Lucey 'Council accused of burying its head in the sand over Rossbeigh coastal erosion'. Irish Times, March 2007

of thousands of wading birds and geese. These birds could winter further north as temperatures rise. Their numbers could also be seriously affected by the flooding of estuaries that currently provided extensive feeding areas.

Warmer summers, as noted already, will also have the effect of increasing the attractiveness of beaches for coastal recreation, while sea level rise could lead to a corresponding concentration of tourism pressure at the remaining sites, including sites that hitherto may have been relatively unaffected by recreational pressure. As noted in Chapter 5, dunes are at particular risk, with many beach nesting birds vulnerable, including terns and ringed plover.

#### *Whale and dolphin watching*

Whale and, more especially, dolphin watching are important activities in counties such as Clare, Kerry and Cork. In 1997, 2,470 dolphin watchers embarked on tours from Kilrush and Carrigaholt. Revenue from these boat trips contributed €30,400 directly or between €108-238,000 indirectly (Rogan, 1998).

Since this time, demand for nature tourism appears to have increased due to trends towards more specialised tourism in Ireland. According to the Royal Irish Academy (as referenced by Fáilte Ireland) 177,000 people went on dolphin, whale or sea watching trips in 2005, spending €7.1 million in the process. Such nature tourism, along with events and walking secured the highest number of hits on the Discover Ireland website.

As with birds, there are fundamental concerns over these wildlife populations too. Consultation carried out with the Irish Whale and Dolphin Group, as part of this review indicated their concern over increased prevalence of toxic algal blooms, the prospect of the reduced availability of prey species such as salmon, and as yet unknown changes in habitat of vulnerable rarer species such as the white-beaked dolphin. Chapter 5 remarks on the vulnerability of seals to severe weather and loss of sites to sea level rise, in particular harbour seals which favour sheltered 'haul-outs'.

However, not all prospects are adverse. The anecdotal evidence reported by nature tourism operators surveyed as part of this review has been of increasing sightings of dolphins, sunfish, and other species, possibly in connection with warming trends. Sharp swings in sea surface temperatures are also reported. The unsettled weather of the summer of 2007, following earlier warm weather in the spring weather, may not be a harbinger of climate change, but is reported to have been an excellent year for sightings of basking sharks and fin whales.

#### *7.4.6 Island tourism*

Tourism plays an important economic role to many of the islands around the coast of Ireland. Many had, until the mid 1990s, been experiencing terminal population decline. Local development agencies have been instrumental in preventing the spiral of population decline experienced by islands such as Gola off the coast of Donegal, and tourism has been an important factor in this strategy.

It would be too easy to claim that islands will suffer unambiguously from climate change. Most of Ireland's populated islands are not at severe risk from sea level rise and island tourism could share in the general benefits that could follow from the effect of warmer weather. However, impacts could be subtle in terms of changes to the Atlantic wildness that is the very essence of the attractiveness of Ireland's islands, particularly for islands such as Tory.

The greater risk is that the economic sustainability of islands will be undermined at a time when the government has invested considerable sums in their infrastructure. Islands such as the Aran Islands, Inishbofin, Clare Island, Arann, and Tory now have reliable ferry services and some have air connections too. However, increased storminess, particularly during the summer months, will impact on tourism with islands being less accessible, and could also threaten non-tourism employment in aquaculture or other sectors. A possibility is that climate change could be another factor increasing dependence on tourism. This, in itself, will put pressure on infrastructure. For instance, water supply is quite constrained on some islands, such as the Aran Islands, which do not receive piped water from the mainland. Some low-lying islands are also vulnerable to drought or contamination by salt water (Cross, 1996).

#### *7.4.7 Golf*

Golf participation, and golf club revenue, should benefit significantly from warmer, drier weather. However, drier conditions will present particular challenges for coastal links courses for which it can be difficult to maintain the water table. Storms and dune re-

cession could also critically affect links courses. Many links courses are already suffering from erosion, including the Royal Dublin and Portmarnock Golf Club in County Dublin, Rosslare Golf Club in County Wexford and Ballybunion Golf Club in County Kerry. In recent years, Rosslare Golf Club has lost an entire green to coastal erosion and similar problems have occurred at the Donegal Golf Club at Murvagh. Although these incidents are the result of natural coastal processes, the increased rate of erosion and risk of storm surges accompanying sea level rise present particular challenges. The environmentally sound approach has been to reinforce dunes through marram transplanting and with fencing or mesh sheets. Where damage has been more severe, courses have either decided to move holes or to use rock armouring, although the latter option has previously been refused in cases where dunes are designated SACs and/ or if it is considered that rock armouring would simply displace the erosion problem elsewhere. In principle, if matters become more serious, links courses could follow dune recession inland where there is available land. Indeed, managed retreat is now being attempted in Scotland. However, this strategy requires a supply of dune building material which in turn would require the abandonment of some holes or permit sand to drift across the course. This option is unlikely to appeal to many course owners until erosion loss becomes inevitable. It may even be necessary to construct artificial links behind the former natural dunes where land is available.

Inland courses, many located beside natural water features, also face management implications due to the susceptibility of grassland monocultures to soil moisture deficits and to fungal diseases such as *Fusarium* and *Curvularia*, the latter having already emerged as a new problem in England during hot summers (Windows, 2004; Isacc, 2004; GUI, GCSAI, Fáilte Ireland 2009). A number of courses rely on irrigation using groundwater.

#### 7.4.8 Walking

Walking represents the most common activity undertaken in the vicinity of our inland waterways (Waterways Ireland, 2005). In the past three years over 100 looped walks have been developed in Ireland. There has been a steady increase in participation levels since 2003, when only 168,000 overseas visitors participated in hiking/walking, to 511,000 overseas visitors participating in 2007.

Waymarked ways and other paths along, or in the vicinity of water, include the Lough Derg Way, the Barrow Way, the Royal and Grand Canal Ways, the Suck Valley Way and the Nore River Walk. Each currently suffers from occasional flooding and consequent maintenance problems. Generally, there is poor countryside access in Ireland compared with other European countries which results in walking routes being created on terrain that may not be suited to wear during wet conditions (e.g. along rivers).

Once again, sunnier or drier weather will encourage more walking, and disproportionately so, close to water. Visible pollution, particularly eutrophication would discourage walking and lead to a significant utility loss. Many walkers are also familiar with the wildlife found along rivers and lakes, so that any loss of species due to pollution or indeed due to invasive species, would have a further adverse impact. More frequent intense rainfall events and subsequent flooding, with associated silt deposits or muddy conditions, would have an adverse impact on footpaths and their use. Recession of lakes due to drought, higher evaporation and lower inflow could also create problems (Arkell *et al.* 2007).

Coastal paths are also vulnerable to erosion, noting also the high costs of maintenance. Various locations around the Ireland are vulnerable, including for example any reinstatement of the Gobbins Coastal Path in Antrim or continued maintenance of the Causeway Coast Path, much of the latter having already been closed in recent years due to the landslide risk, and the Bray to Greystones coastal trail which has been severely eroded in parts. Although a natural occurrence, erosion will accelerate under stormier climate regimes. This could threaten, or at a minimum, create greater difficulty in implementing Fáilte Ireland's strategic proposal (as identified in the Tourism Product Development Strategy 2007-2013) to develop a national coastal walkway. From now on, planning the precise route of any coastal walkway will necessitate taking into account the likely future effects of coastal erosion and sea level rise, in other words, climate-proofing the infrastructure.

#### 7.4.9 Other water-based activities: surfing, wind or kite surfing, and diving.

Once again, warmer weather can be expected to increase activity in adventure sea sports such as all types of surfing and diving. Currently, an estimated 17,800 people in Ireland are involved in surfing or sailboarding, while 9,000 are believed to participate in diving with 3,000 being members of the Irish Underwater Council (Marine Institute referenced by O'Driscoll *et al.*, 2007).

The prospect of more stormy winter conditions could benefit board surfing activities, although there is a risk that some popular surf breaks could be submerged. By comparison, kite surfing ideally requires consistent winds. As with sailing, there are safety concerns

too. Water quality is also a concern for these interest groups, especially with regard to waste water treatment (including storm out-flow). Diving could be affected by cloudier conditions underwater brought on by storms, but the main impact mentioned in consultation with the Irish Underwater Council might be restricted boat access to offshore reefs such as those off Fastnet Rock or the Skelligs due to an increase in extreme weather events, particularly storms, during the summer months. Of course, adverse impacts on sea life would also be a significant factor and are hard to predict in that warmer weather could attract more exotic species which could have an as of yet uncertain impact on existing sea life species.

## 7.5 Conclusion

Relative to Mediterranean regions, Ireland as a tourism destination may benefit from increased visitor numbers due to climate change. However, there will be adverse impacts associated with this and it will be necessary to prepare for these. A subtle change could follow from the transformation of the cultural landscape from that with which we, and tourists, are familiar, such that Ireland is no longer quite the same destination as before. Given that much of Ireland's 'unique selling point' is based upon differentiation from other destinations, on cultural and landscape grounds in particular, it will be important to protect those features that distinguish us from other popular destinations.

While it is likely that there will be gains to tourism from climate change, namely as a result of increased summer sunshine and decreased summer rainfall, there are also a number of significant risks including, for example, those of eutrophication of surface waters or the possible inundation of popular beaches and seaside resorts and increases in invasive species at the expense of native species. Careful management of climate-exacerbated pressures such as water pollution will be essential in order to safeguard positive destination image in the long term. The successful implementation of the Water Framework Directive is very important in this regard. Increased visitor pressure may also damage our natural heritage if poorly managed (e.g. dune erosion).

It is therefore vital that the tourism product is of high quality and that sustainable tourism management policies are employed to address the potential climate change impacts identified in this report. Table 7.3 provides a summary of the predicted climate change impacts on the range and quality of tourism activities, and also suggests some specific activity related adaptation measures. More general policy and strategic adaptation measures which could assist all tourism stakeholders to adapt to the challenges of climate change are outlined separately in Section 7.5.

Table 7.3 Summary of tourism impacts in Ireland

	Temperature	Precipitation	Sea level rise and increased storminess	Examples of appropriate adaptation measures
<b>GENERAL</b>				
<b>Tourist numbers</b>	Warmer temperatures are likely to attract tourists, especially from southern Europe where climate becomes uncomfortable, as well as encouraging people to stay at home.	Lower summer precipitation will encourage more visitors and an extension of the season. Extreme weather events could affect the enjoyment of certain tourist activities.	Tourist distribution is likely to change but some popular beaches may be adversely affected by erosion.	Pro-active and sustainable planning required to manage tourist numbers and to protect sites of heritage value. Need to manage natural resources such as water and energy use.
<b>Landscape</b>	Certain change in the familiar Irish landscape, but with uncertain implications for tourist numbers.	As above.	May be a loss of some well-known and popular areas.	Manage within constraints of climate through targeted agri-environmental measures, e.g. as currently applied in the Burren and Shannon Callows
<b>ACTIVITIES</b>				
<b>Cultural tourism</b>	Warmer temperatures are likely to attract tourists, especially from southern Europe where climate becomes uncomfortable, as well as encouraging people to stay at home.	Heavy rainfall, floods and drought for heritage will result in conservation challenges for our built and cultural heritage.	Threat to coastal structures (attractions and facilities) from storms, sea level rise and coastal erosion.	Pro-active and sustainable planning required to manage tourist numbers and to protect sites of heritage and tourism value. Forward planning and coordination on river basin and coastal management will be necessary.
<b>Inland angling</b>	Change in existing structure of fish populations. Pressure on cold water species such as salmon. Greater risk from eutrophication directly. Risk from invasive species.	Change in existing structure of fish populations. Low flows exacerbated by greater abstraction. Greater risk from eutrophication as less dilution.	Stormier weather will keep craft in harbour.	Reinforce efforts to reduce diffuse pollution. Coordination required at river basin level between planners, OPW, ESB, NPWS, agri and other interests.
<b>Sea angling</b>	Change in species composition		Stormier weather presents good conditions for shore angling, but would keep craft in harbour.	Investment to insure safety. A need to develop regional climate data. Improved weather forecasting.
<b>Cruising</b>	Increased attractiveness of water-based holidays and boat ownership. Possibly compromised by elevated pollution risk.	Risk mainly from low flows. Canal recharge. Risk from unsightly pollution. Risk from extreme rainfall events.		Coordination required to manage pollution, river flows and planning. Investment in water storage facilities to collect water during the winter for summer recharge. More dredging required of canals to their design depth. Integration of abstraction, hydroelectric demand and heritage. More automated facilities to permit faster barrage and lock gate reaction times to low and high flow situations. Warning system for boaters providing information on velocities at critical points and traffic and mooring management to allow boats to negotiate difficult areas safely.



	Temperature	Precipitation	Sea level rise and increased storminess	Examples of appropriate adaptation measures
<b>ACTIVITIES</b>				
<b>Inland sailing and kayaking</b>	Increased attractiveness of water-based recreation. Possibly compromised by pollution risk.	Lower flows at times of year that are popular for kayaking.	Stormier weather will keep craft in harbour. Certain moorings and harbours may be less usable if exposed to particular wind directions.	Coordination required as above to manage pollution, river flows and planning.
<b>Ocean sailing</b>	Increased attractiveness of water-based recreation.		Risks to mooring facilities from sea level rise. Threats from extreme events. Less reliable winds.	A need for regional climate data. Improved weather forecasting.
<b>Beach use and swimming</b>	Increased attractiveness of water-based recreation. Possibly compromised by pollution risk and crowding. Pressure on beach nesting birds. Possible increase in invasive species in inland waters could lead to health and safety risks to swimmers.	Extension of season. Some risk of pollutants being washed onto beaches by heavy rainfall events.	Submergence of some popular destinations. Greater use of other beaches. Recession or loss of some dune systems. Some risk from sewage outfalls.	Coordination required as above to manage pollution and use. There is an urgent need for an Integrated Coastal Zone Management strategy for Ireland.
<b>Nature tourism</b>	Increased participation, but changes in some key wildlife populations, including cliff breeding birds and wintering waders, seal populations etc. Increased participation could also lead to direct interference with wildlife populations.	Cumulative summer impact on species together with higher temperatures. Threats to some wetland habitats.	Submergence of some important habitats and sites with salt marsh and shingle beaches at particular risk. Some opportunities from habitat creation associated with managed retreat.	There is an urgent need for Integrated Coastal Zone Management. Enlightened approach needed for coastal protection. Further research required into the principle of managed retreat. Sustainable management of visitor numbers also required.
<b>Golf</b>	Increased participation levels.	Difficulties of maintaining soil moisture and increased problems from fungal disease, particularly on inland courses.	Physical erosion and flooding of links courses.	Sophisticated green management required e.g. development of an integrated pest management plan, nutrient monitoring, change in grass seed etc. Acceptance of some level of coastal erosion due to sea level rise and increased storm surges. As part of an Integrated Coastal Zone Management strategy, the concept of managed retreat should be investigated further.
<b>Walking</b>	Increased attractiveness of locations beside water. Possibly compromised by pollution risk	Recession of lakes during drought. Flooding of paths during winter, including physical damage.	Erosion of coastal footpaths. Danger to walkers safety from extreme storm events and storm surges.	Climate proofing of future investment in footpaths, and in particular in relation to coastal walks. Sustainable access to meet demand. Promotion of Leave No Trace principles on all walking routes.
<b>Active sea sports</b>	Increased attractiveness of water-based recreation		Stormier winter weather could present good conditions for surfing, but problems from reliable winds for kite surfing and sea kayaking, loss of surf breaks for board surfing	Ensure increased participation is sustainable and sensitive to the environment and other users.

## 7.5 Adaptation

This section highlights the various measures that can be taken by the tourism industry to adapt to the predicted and likely impacts that will arise from climate change as outlined in the preceding sections of this chapter. These recommended adaptation measures are divided into two parts, firstly those that will be necessary to deal with the impact of climate change on tourism, and secondly, those that the industry should take to reduce the impact of tourism on climate change.

### 7.5.1 Adaptation – impacts of climate change on tourism

The First International Conference on Climate Change and Tourism was held in Djerba, Tunisia in 2003, with the Second International Conference held in Davos, Switzerland in October 2007. Despite these meetings and a growing number of conferences at International, European and National levels, awareness of climate change in the industry remains low. This is unfortunate given the close relationship between climate and tourism, and between vulnerable heritage and tourism. Tourists are also highly flexible in their destinations and are not tied to particular locations or operators. Ultimately, individual tourists are more adaptable to climate change than the destinations they visit.

Whatever the numbers, climate change will lead to some significant changes in tourism flows over time. Locations at particular risk in Europe include the Mediterranean and Alpine ski resorts. Impacts in Ireland will be moderated by our temperate climate. Undoubtedly, some of these impacts will be positive from a tourism point of view. Warmer, drier summer weather will increase the appeal of many Irish coastal resorts and of water-based and other outdoor activities.

In addition, a significant increase in visitor numbers may also put pressure on the conservation and management of our cultural heritage assets. Sustainable management policies will be required to ensure that cultural heritage assets are properly managed and maintained and that increased visitor numbers do not undermine the asset itself.

With sufficient forward planning, the tourism industry and relevant planners can be assisted to adapt to these predicted impacts. Adaptation measures will be required at a national and local level and should at a minimum include the following:

**(a) Greater awareness within the industry of the likely impacts of climate change and how the industry can adapt to these changes.**

Fáilte Ireland recently (November 2008) published a strategy document entitled *Facing the Challenges of Climate Change- Fáilte Ireland's Carbon Strategy*. The aim of this strategy is to introduce the issue of climate change and carbon management to the industry in conjunction with the Government's existing CHANGE campaign. A higher level of awareness among tourism businesses about the effect and implications of climate change on their businesses will help businesses to adapt to the predicted changes.

**(b) The introduction of Integrated Coastal Zone Management (ICZM).**

ICZM would provide a co-ordinated approach to the management of the coastal zone, taking into consideration the natural, built, and tourism assets of the coastline to ensure that a balanced and coherent approach is taken to the management of our coastline. Also, better information is needed for the tourist industry on any unintended negative consequences that can arise as a result of hard coastal defence works and information on the alternatives.

**(c) The introduction of a National Landscape Strategy**

There is a need for the recognition of the tourism value of landscape and the threat from climate change to be placed at the heart of a National Landscape Strategy. Conservation of landscape character should be linked to sustainable land use and sustainable rural communities.

**(d) Sustainable development of tourism infrastructure**

Co-ordinated and strategic planning is required by Local Authorities and the tourism industry to ensure the protection of the tourism/amenity resource from over exploitation.

**(e) Sustainable management of tourism assets**

Better recognition of the relationship between heritage (both natural and cultural) and tourism dependence on the sustainable management of these assets. Co-ordination with heritage and tourism bodies on all tourism development at a na-

tional and local level (including regional and local development agencies) must be promoted.

**(f) Climate proofing of tourism infrastructure**

Climate proofing of tourist/recreation related infrastructure, in particular, in relation to the extension or development of any coastal works such as the proposed national coastal walk, or works along riverbanks and inland waterways which may be susceptible to flooding.

**(g) The need for diversification and innovation of tourism products**

Product diversification and innovation should be promoted and developed within the industry. Climate change offers a range of opportunities for the development of new tourism offerings such as nature tourism. Also there is a need to offer visitors a low emissions choice. As a result of the effort made by any tourism businesses to reduce their carbon emissions, and indeed their environmental footprint, visitors could be offered a greater choice of products which are environmentally friendly. Fáilte Ireland will provide additional marketing opportunities to these businesses as part of a new 'green tourism' section of its consumer website [www.discoverireland.ie](http://www.discoverireland.ie) (refer to Fáilte Ireland's Carbon Strategy document, 2008).

### 7.5.2 Adaptation - impact of tourism on climate change

The tourism industry is also a significant contributor to climate change through its high relative emissions of greenhouse gases. Research carried out by the United Nations World Tourism Organisation (UNWTO), in association with the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO) indicates that CO<sub>2</sub> emissions from international tourism (including all forms of transport), accounted for just under 5% of global emissions in 2005. New Zealand, an island destination like Ireland, has determined that tourism accounts for approximately 6% of national GHG emissions (New Zealand Ministry for Tourism, (2008).

The recent Second International Conference on Climate Change in Tourism held in Davos, Switzerland in October 2007 under the auspices of the World Tourism Organization and United Nations Environment Programme, heard that a business-as-usual scenario could involve CO<sub>2</sub> emissions in global tourism rising by 152% by 2035. The Davos Declaration which resulted from this conference called for greater efforts to mitigate greenhouse gas emissions and for the industry to adapt to changing climate conditions. This includes a need for:

- i. an awareness of tourism's relationship with the natural environment; and
- ii. greater policy coordination and the integration of tourism in local and regional adaptation plans.

Much remains to be done in Ireland in these respects.

There is however some change in the pipeline such as the inclusion of aviation in the EU Emissions Trading Scheme as and from 2012. Air travel and car journeys are significant contributors of GHGs, with tourism related transport accounting for approximately 2% of all GHG emissions (UNWTO, WMO AND UNEP, 2005). Unfortunately, Ireland, as an island nation, is heavily dependent on air travel and many tourism operators have benefited in recent years from the greater availability of cheap airfares and short breaks. Holidays in Ireland have also traditionally included a high level of touring by private or hire car. Public transport infrastructure in Ireland is considered to be poor compared with many other European countries and supply is largely focused on Dublin.

Through the implementation of the Fáilte Ireland's Carbon Strategy (2008), the tourism industry can play its part in contributing to the EU targets to reduce GHG emissions. Over the next two years, Fáilte Ireland, in association with the Department of the Environment, Heritage and Local Government, through the CHANGE campaign will seek to determine the carbon footprint of the tourism industry in order to benchmark its current environmental performance and monitor progress in the future.

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## Part 4: Summary and Conclusion

### Chapter 8. KEY ISSUES AND RECOMMENDATIONS

**Authors: Beatrice Kelly (Heritage Council) and Mary Stack (Failte Ireland)**

This chapter draws together the main issues from Chapters 5, 6 and 7, into six main themes for future consideration:

1. Integration of heritage, tourism and climate change strategies into coherent national policies
2. Adaptation
3. Research
4. Awareness Raising
5. Training
6. Resource Management

For detailed recommendations on particular aspects of heritage, or tourism and heritage, the reader should refer to the relevant chapter.

#### Projected changes to Irish climate

The climate change scenarios for Ireland have been identified and discussed in detail in Chapters 3 and 4 and are summarised briefly here. Ireland is likely to experience a potential mean temperature rise relative to 1961-90 period of up to 2.1°C to 2.7°C by the 2080s with the autumn months warming the most. Rainfall will become more seasonal with wetter winters and dryer, more overcast, summers. More extreme rainfall or precipitation events will occur, changing the current pattern of 'low duration, low intensity'. The likelihood of inland flooding will increase as a result, in particular, in the west and the midlands. The whole country will experience scarcity of water in the late summer and autumn, possibly more so, in the east and south.

Sea levels around Ireland will rise by at least 18- 59cm by the 2080s. This will be exacerbated by more storm events, storm surges and increased wave energy. Coastal flooding, caused by a combination of these factors, and the resultant coastal erosion will be more prevalent, placing low-lying areas, and soft coastlines at particular risk.

These changes will affect many aspects of our cultural and natural heritage to varying degrees, and subsequently will impact our tourism industry which relies on our heritage as its raw material. This study has focused on the coastal and inland waterways heritage and tourism products, in part due to their vulnerability in relation to impacts of climate change, and their importance to the tourism industry.

#### Summary of findings

The projected impacts on heritage and tourism have been explored in Part 3 and vary in severity depending on the aspect of heritage and its location. For example, cultural sites in the intertidal zone, such as archaeological sites located on a glacial till shore line, are at higher risk of damage and elimination than an eighteenth-century town house in Dublin. Coastal wetlands located in areas dominated by human activity are also at high risk (e.g. the salt marsh around Bull Island in Dublin Bay). However it is hard to separate the effects of change as a result of predicted changes in climate, from those which result from human activity (e.g. eutrophication of our inland and coastal waters, development on flood plains and the coastal strip and fragmentation of habitats). Furthermore, our knowledge about our stock of heritage and its condition is patchy.

While the direct effects of climate change on heritage and tourism must be considered, the indirect impacts from mitigation and adaptation strategies and measures also have importance for heritage and tourism. For example the impacts of constructing wind farms on- and off-shore, and the growing of new bio-mass crops may have significant impacts on our landscapes and seascapes. Hard engineering schemes to prevent both coastal and inland flooding can also impact negatively on cultural and natural heritage.

These adaptations to climate change can lead to competition, and potentially incompatibilities, between aspects of cultural and natural heritage. An example of this being adaptation proposals such as managed alignment where the coastline is allowed to erode or, in some cases, is opened to coastal flooding and inundation by the sea. This can be beneficial to natural heritage by creating

new wetlands or allowing coastal habitats space to advance inland; however, it may cause the destruction of cultural sites such as occupation sites. The Blythe Estuary in the UK is one such case in point. In such cases a rounded approach, based on best available information will be needed, evaluating the importance the resources in question alongside the natural processes occurring at the site in question. It may also be the case that the rate of sea rise and erosion is such that adaptation measures are not feasible.

Likewise, incompatibilities between the needs of heritage and the tourism industry over adaptation strategies may also arise. For example, hard engineering works to protect coastal tourism assets or infrastructure will have to be considered in light of natural coastal processes and the potential long-term impacts on the heritage value of the area. It must be ensured that protection works do not exacerbate the problem, which may lead to the eventual undermining and possible loss of the tourism asset. These situations will need to be assessed on a case by case basis; more information is required on the scenarios that are likely to arise.

## Key Issues

The key issues derived from Chapters 5, 6 and 7, have been drawn together here under six main themes as follows:

### 1. Integration of climate change policies with heritage and tourism

For heritage and tourism to receive sufficient attention and resources to ensure a relatively balanced future, greater integration of heritage and tourism issues into mainstream plans will be necessary. As a first step, heritage and tourism plans and strategies, such as the National Biodiversity Plan, county heritage plans, as well as national and regional tourism strategies, should include policies and actions relating to climate change. These policies and recommended actions should then be included in climate change adaptation strategies at national and county level. At present, biodiversity is sometimes mentioned while cultural heritage and tourism is rarely considered.

This need for integration reflects the necessity for a more cohesive management approach at an institutional level. While the Government is planning a National Adaptation Strategy for 2009 with an inter-departmental climate change committee, greater interaction and planning between sectors is required. In particular, the development of a national policy on Integrated Coastal Zone Management is critical in devising a coherent, appropriate response to rising sea levels and coastal erosion (Sections 5.4.5 and 7.5.1.). The Water Framework Directive and the OPW flooding guidance are steps towards a more joined-up approach which should be used to inform other areas of national policy. Greater co-ordination between heritage and tourism bodies at national and regional level is also needed (Section 7.5.1.).

### 2. Adaptation

As discussed in the introduction to Chapter 3, even if concentrations of greenhouse gases were maintained at the levels recorded in 2000, global warming would continue at a rate of 0.1°C to 0.2°C per decade for the next twenty years (IPCC, 2007a). Even without any mitigation of impacts, a significant adjustment of current practices will be needed to help our coastal and inland waterways heritage adapt to the likely changes. Among the adaptation measures identified for natural heritage is the need to reduce existing stresses on our habitats and wildlife which are likely to exacerbate the effects of climate change. For example, a significant number of Ireland's watercourses contain excessive nutrients. Much more determined actions will be needed to reduce this problem given the expectation of warmer, drier conditions (Section 5.4.2). Landscape permeability and the connection of habitats should also be a requirement of land use planning and landscape management (Section 5.4.1), while sea level rise demands a co-ordinated national response which takes on board the concept of managed alignment of low lying coasts. This will have implications for cultural heritage and tourism too.

Built heritage requires greater levels of inspection, monitoring and maintenance of structures, and the installation of flood warning systems. Emergency planning to cope with damage caused by extreme events such as storms or flooding are also needed (Section 6.7.3). Specifically for the coast, it is necessary to decide whether to accept certain losses to cultural heritage and to manage the retreat by recording the impending loss or whether to re-locate items of heritage away from a threatened site (Section 6.7.3).

The tourism sector (both industry and promoters) will also have to adapt to the predicted impacts of climate change (as outlined in Section 7.5). This will involve a number of measures such as climate proofing of tourist/recreation related infrastructure, in particular, in relation to the extension or development of any coastal works such as the proposed national coastal walk, or works along riverbanks and inland waterways which may be susceptible to flooding. In addition product diversification and innovation should be promoted and developed within the industry. Climate change offers a range of opportunities for the development of new tourism offerings such as nature tourism.

### 3. Drawing up of a research agenda

One of the main findings of this study is the need to improve our baseline knowledge of many aspects of our heritage. With more precise baseline knowledge it will be possible to start monitoring for the potential impacts of climate change on heritage. It will also be possible to prioritise those sites and species of particular vulnerability and which may require special attention to ensure some form of survival in the face of the climate challenge. Knowledge of the state of heritage will also inform the tourism industry on opportunities for the development of new tourism offerings in the future and also where increased visitor numbers may have a negative impact on heritage.

Research is also needed on public attitudes to the interactions of climate change, heritage and tourism, as this would inform general awareness campaigns or information provided at specific sites.

Vulnerability mapping should also be carried out as part of the research programme. This mapping could identify geographic areas of Ireland at greatest risk of coastal erosion, the types of heritage that can be found there, and the tourism activities relating to that heritage (Section 6.7.4). There are a variety of resources to hand for this: the OPW flood mapping (inland and coastal) ([www.opw.ie](http://www.opw.ie)) and INFOMAR new bathymetry, as well as the National Inventory of Architectural Heritage (NIAH), Records of Monuments and Places (RMP), Natural Heritage Areas (NHAs), and Natura 2000 sites. This would also assist with any climate-proofing of tourism products or infrastructure.

### 4. Raising awareness

Higher levels of awareness and understanding of the potential impacts of climate change are required among the general public and political decision makers. In particular, better understanding of coastal processes may obviate requests for unsustainable coastal defences (Section 6.7.3). The potential impacts on heritage need to be communicated to heritage professionals to inform their activities and future plans as well as allowing them to join the general debate. Tourism providers and policy makers also need to be aware of the potential implications for their business and industry respectively caused by climate change, and of the potential vulnerabilities of heritage as a result of additional tourism pressure. This would also increase the understanding for the need to manage heritage sustainably, in particular, because of tourism's dependence on these assets.

### 5. Training

Training is required for those involved in heritage (policy and site specific) to manage the changes that may arise from climate change. Training should include the identification of appropriate adaptation measures, ensuring that national adaptation policy does not impact negatively on heritage, and by providing alternative habitats and space for nature (Section 5.4.1; Section 6.8; Section 7.5.1). Tourism providers and promoters may require training in climate proofing projects, and ensuring that the impacts of their business are compatible with heritage needs. Emergency preparedness (i.e. for coping with extreme weather events and their impacts on heritage sites and related tourism facilities) is also an area in which both heritage and tourism professionals must receive training.

### 6. Resource management

There will inevitably be a cost associated with any mitigation or adaptation measures put in place to tackle climate change, including those mentioned above, from training, awareness raising, research etc, but there will also be capital investment costs. *The Economics of Climate Change*, more commonly known as the Stern Review, found that the cost of action to combat climate change now would cost far less (approximately 1% of global Gross Domestic Product) than the cost of inaction or repair (approximately 5% of global Gross Domestic Product) at a later stage. Therefore costs associated with both climate change adaptation and mitigation should be part of all future Government investment strategies and considered as part of any future development plans for the country at national, regional, county, and local area levels.

The costs, financial and otherwise, of protecting all our heritage and tourism resources need to be placed against our ability to carry this out. Priorities will have to be identified and trade-offs made on what to protect and conserve, and what to let go, based on high quality information on the significance of the heritage resource, alongside the values that each holds for the community.

Overall, it is clear that uncertainty is the only certain thing in the area of climate change. It behoves us to react in some way despite this uncertainty. Strong political leadership backed up by well-informed policies and resources are needed to ensure that appropriate mitigation and adaptation strategies are put in place to reduce impacts and to manage our heritage and its dependant tourism products for future generations.

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