MCCIP Ecosystem Linkages Report Card 2009
Coastal economies and people

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Please cite this document as:
Cooper, JAG (2009) Coastal economies and people *in* Marine Climate Change Ecosystem Linkages Report Card 2009. (Eds. Baxter JM, Buckley PJ and Frost MT), Online science reviews, 18pp. www.mccip.org.uk/elr/coasts

1. THE COASTAL ECONOMY OF THE BRITISH ISLES

The United Kingdom coast is 12,429 km long and that of the Republic of Ireland, 1448 km (WRI, 1996). The entire population of the United Kingdom and Republic of Ireland lives within 100 km of the coast. Over 70% of the Scottish population lives within 10 km of the coast and 20% within 1 km (www.scottish.parliament.uk /nmcentre/news/news-comm-07/cenv07-003.htm). In Ireland 63% of the population lives within 16 km of the coastline (Sweeney *et al.,* 2008). The coastal population is, however, unevenly spread and sparsely inhabited rural coastlines contrast with densely populated conurbations. Most of the major cities of the British Isles are in coastal locations and these centres of habitation, trade and industry are important economic resources. Ten of the 20 most populous cities in the UK are coastal. They are: London (7.2 million), Glasgow (560,000), Edinburgh (450,000), Liverpool (440,000), Bristol (380,000), Cardiff (310,000), Belfast (280,000), Newcastle (260,000) Brighton (248,000) and Hull (240,000) (www.ukcities.co.uk/populations). The adult resident population of the 43 main seaside resorts in Great Britain is over 3.1 million (www.britishresorts.co.uk/tourismfacts.aspx). 95% of Britain's trade is conducted through its ports and the value of goods passing through ports in 2006 was £340 billion (www.britishports.org.uk/public/uk_ports_industry/market_overview). The coast and its resources are not only valued by people who live, work and recreate there, but they provide economic benefits to society as a whole through their contribution to GDP via several economic sectors. The FCR (2000) identified the following broad economic sectors in coastal zones:

- Sea fisheries
- Fish farming
- Agriculture and food
- Forestry and forest products
- Mineral extraction
- Shipbuilding
- Petrochemicals, refining
- Manufacturing sectors
- Power generation
- Ports and shipping
- Passenger ferries
- Leisure Marinas
- Airports and air transport
- Tourism and leisure
- Financial services
- Residential housing
- Government activities
- Military and defence

There are different approaches to assessing the value of the coast to the economy. One is to determine the economic value of sectors of human activity. Another is to value 'Ecosystem Services' or the "services provided by the natural environment that benefit people" (DEFRA, 2007). A third approach is to consider the market value of property (land, physical infrastructure and housing) in the coastal zone. These approaches overlap to various extents and none is completely comprehensive, however, they represent different ways of assigning an economic value.

A review of the importance of the marine sector of the UK economy (Pugh and Skinner, 2002) includes several distinct coastal activities (Figure 1). Chief among these are leisure (i.e. recreation and tourism: £19.2 billion), shipping (£5.2 billion), fisheries (£2.4 billion including aquaculture at £328 million), ports (£1.7 billion) and environment (including water treatment, £1 billion). Seaside tourism revenue of £17 billion underscores the overwhelming importance of tourism and recreation at the coast. In 2006 British residents took 27.1 million overnight seaside trips of which 22.5 million were holidays. The latter generated a tourism spend of £4.2 billion (£3.3. billion in England, £0.6 billion in Wales and £0.29 billion in Scotland). An additional 270 million day trips to the coast generated £3.1 billion in spending. (www.britishresorts.co.uk/tourismfacts.aspx). Irish marine activities (Douglas Westwood, 2005) follow a similar overall pattern to those of the UK, although the values are proportionally smaller. Marine tourism and leisure in Ireland, for example, was valued at €709 million/year between 1999 and 2003 and Fisheries €951 million/year for the same period.

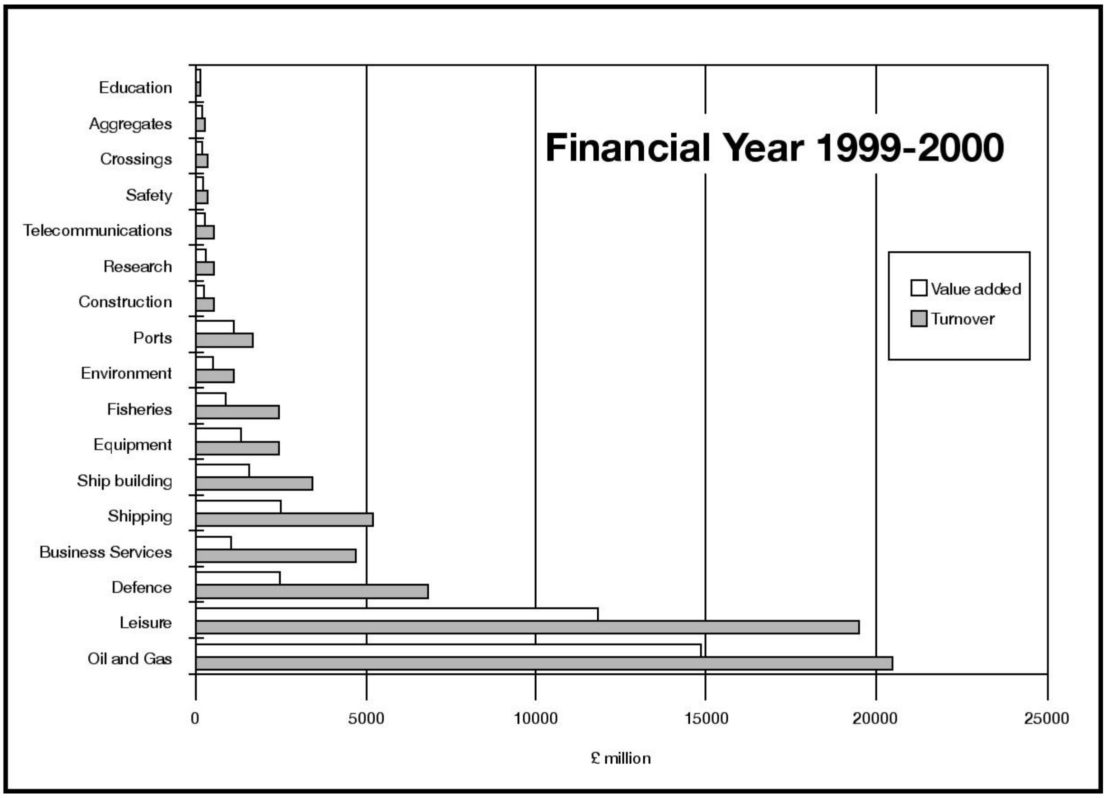

Figure 1. Contributions of marine-related activities to UK economy for financial year. 1999-2000 (after Pugh and Skinner, 2002)

The ecosystem goods and services provided by various coastal habitats have also been used to assign economic value to coasts (Costanza *et al.*, 1997). Ecosystem services listed by DEFRA (2007) include:

- Natural resources for basic survival, such as clean air and water
- A contribution to good physical and mental health, for example, through access to green spaces, both urban and rural, and genetic resources for medicines
- Natural processes, such as climate regulation and crop pollination

- Support for a strong and healthy economy, through raw materials for industry and agriculture or through tourism and recreation
- Social, cultural and educational benefits, and wellbeing and inspiration from interaction with nature.

Ecosystem services is a useful way of viewing the link between future ecosystem change and coastal economies as a value can often be placed on each of the services provided. This approach has been advocated by Beaumont *et al.* (2007) on the basis of its compatibility with the 'Ecosystem Approach' to integrated management. It was applied at a broad scale by FCR (2000) to assess the value of ecosystem services of the European Union coasts. Values were not cited directly for ecosystem services, but the socio-economic benefit of good stewardship through ICZM of coastal ecosystem services for the UK was estimated at £96 million for tourism and industry and £66 million for habitat enhancement using the Costanza *et al.* (1997) values. The equivalent values for Ireland were £4.9 million and £19 million.

To illustrate the approach, English Nature (2006) provides an assessment of ecosystem services in England provided by its 385,000 Ha. of intertidal habitat and discusses approaches to evaluating them. More recently Beaumont *et al.* (2008) applied the goods and services approach to value marine biodiversity in the UK. With some caveats regarding the various methodologies, Beaumont *et al.* (2008) identified the following selection of services and associated monetary values for UK marine biodiversity (the total for such services for which values are available is at least £14 billion/year excluding nutrient cycling of coastal waters whose value is one or two orders of magnitude greater than the total for other services but which is subject to much uncertainty):

Production Services:	Food £513 million Non-food £81.5 million
Regulation Services:	Gas and climate regulation £0.4-8.47 billion Dampening of environmental disturbance £300 million Bioremediation of waste (not known)
Cultural Services:	Cultural heritage and identity (not known) Education, research, understanding £317 million Leisure and recreation involving marine organisms £11.77 billion Non-use values £0.5-1.1 billion
Supporting services:	Nutrient cycling £800-2320 billion Resilience and resistance (not known) Provision of habitat by living marine organisms (not known)
Option Use:	Unknown potential future uses (not known)

As ecosystems change in response to climate change, there is a change in the value of the ecosystem services they provide. Depending on the strategy adopted, different ecosystem services can result. An example of the case of a managed realignment scheme at Wareham is provided by Eftec (2007) in which the potential ecosystem service values resulting from different adaptation strategies are presented. Similarly, Turner *et al.* (2007) assessed the economic implications of different adaptation strategies on the Humber.

Estimates of the value of coastal land and built structures are not easily obtainable. However, for the purposes of this report the value of properties at risk from climate change effects is most pertinent. The main threats to buildings and infrastructure at the coast are coastal erosion and flooding. Recent estimates are that 1,062,000 flats and houses, 82,000 businesses, 2.5 million people and 2 m acres of agricultural land worth about £120 billion are at risk from flooding and coastal erosion in England and

Wales (DEFRA, 2001). Of this, at least £10 billion of assets are at risk from coastal erosion (Office of Science and Technology, 2004). Annual damage costs are over £1 billion with over £450 million being spent on flood management in 2003-2004 (DEFRA, 2002, Foresight, 2004). Foresight (2004) estimates that with current flood management policies and expenditure, annual flood losses would increase by between £1 billion and £27 billion by the 2080s.

2. RELEVANT CLIMATE CHANGE TRENDS

Climate change (as described in MCCIP annual report cards: www.mccip.org.uk/arc) affects coastal economies and people directly and indirectly via a complex web of interactions. Because human activity is also subject to change in response to social and economic influences, it is difficult to identify definite climate-related effects on coastal economies and people to date. In contrast, there are many more studies that explore the *potential* future impacts on human activity. Consequently, there is only a low degree of certainty regarding the role of climate change to date and a still lower degree of certainty regarding the impact of potential future changes on people and economies.

The direct impacts on coastal people and economies arise mainly from warming, sea-level rise, higher incidence of severe winds and ocean acidification. Arising from these are changes in coastal geomorphology, (particularly coastal erosion), flooding and consequent loss of, or change in, coastal habitats. These losses and changes contribute together with direct climate change drivers to changes in coastal and marine ecosystems that are manifest in alteration of plankton, fish, seabed and bird communities. These too affect each other. This array of climate-related changes has the potential to affect human activity at the coast (shipping, tourism, built structures, fisheries and aquaculture are considered individually in MCCIP report cards: www.mccip.org.uk/arc), but it is clear that many of the relationships are poorly understood and that many feedbacks are involved, not least from human adaptation to real or perceived changes.

3. CLIMATE CHANGE IMPACTS ON PEOPLE AND ECONOMIES

3.1. Introduction

People occupy the coast with variable density and use the coast in a variety of ways. The actual and potential changes in climate and resultant ecosystem responses have implications for all aspects of human activity at the coast. In this report, the changes in several important sectors of the coastal economy are considered and the linkages between them and the climate change drivers are considered.

The impacts of coastal change will be felt in many areas of activity including: Conservation, tourism, infrastructure, transport (ports and shipping, railways, roads), fisheries. The importance of each of these sectors to the economy varies from region to region, so many of the effects will not be spread evenly across the British Isles. At a national level, in Ireland, it is, however, estimated that a 1m rise in sea level would put 250,000 people at risk. Adaptation measures to maintain the existing socio-economic situation under such a scenario would cost from €10 million to €340 million/year (0.02-0.5% GDP) (Boelens *et al.,* 2005).

3.2. Nature Conservation

A variety of nature conservation designations have been applied in coastal and marine areas. There are five coastal National Parks and 26 coastal AONBs in

England, Wales and Northern Ireland. England and Wales have 45 Heritage Coasts covering 1500 km of coastline. The National Trust owns 900 km of coast in England, Wales and Northern Ireland and there are Unesco World Heritage sites and marine nature reserves in coastal areas. Scotland has 415 coastal SSSIs covering 290,000 Ha., and 33 National Nature Reserves (NNRs) covering 41,000 Ha. Of the 616 Natura 2000 sites in the UK, covering 1.7 million Ha., a significant number are in the marine and coastal environment (www.jncc.gov.uk/page-1480). There are additional European obligations in coastal and marine nature conservation in relation to the establishment of marine protected areas. Nature conservation faces threats from sea-level rise, coastal erosion (and local accretion) and habitat loss. Ocean acidification also has important implications for marine habitats including maerl beds and mussel and oyster reefs. Management responses to such threats are constrained by, and impact on, other elements of the coastal economy.

Two main socio-economic impacts arise from the impacts of climate change on natural habitats. One is in the direct costs of maintaining the favourable status of conservation sites. The second is from the impact on the ecosystem services provided by natural habitats.

There is a requirement for governments to maintain the attributes for which European sites (Natura 2000 sites) were designated and financial penalties for failure to comply. These sites may experience changes in habitat extent and ecosystem structure as a result of natural responses to climate change or by decisions to intervene or cease intervening in coastal processes. Gardiner *et al.* (2007) concluded that sea level rise will create difficulties in meeting the requirements of the EU Habitats Directive within individual designated sites, particularly those containing saltmarsh and mudflats. There is a requirement to create compensatory habitats for those that are lost. Lee (2001) estimated that the continuation of historic trends of shoreline evolution would lead to a loss of freshwater and brackish habitat of about 4000 Ha. in England and Wales. Costs for replacement of those habitats were estimated at £50-60 million (2000 prices). Grey dune habitats being by definition mature and stable cannot be easily replaced. They are thus particularly susceptible to sea-level rise and coastal erosion; they may either disappear or be replaced by embryo dunes. Lee (1998) estimated that 129 ha of sand dunes and 130 ha of vegetated shingle could be lost over the next 50 years In England and Wales. In Ireland, there have been net losses in 11 of 16 designated coastal habitats, with significant losses (> 10%) in coastal scrub and marram dune habitats since the EU Habitats Directive came into force in 1997 (NPWS, 2008).

Conservation of coastal geological sites such as contained in Heritage coasts, SSSIs/ASSIs and World Heritage Sites (Giant's Causeway, Northern Ireland, Dorset's Jurassic Coast and St Kilda) require that erosion continue in order to shape landforms and refresh exposures.

The costs of meeting formal nature conservation obligations and in maintaining natural habitats outside designated sites in the face of climate change have to be viewed against potential costs to ecosystem services of habitat and biodiversity loss. Impacts from loss of coastal habitat extend across all categories of ecosystem service. *Regulation Services* would be impacted if the dampening of wave action by wetlands and beaches was reduced by loss through erosion. *Production Services* would be affected through potential ecosystem change impacts on commercial species. *Cultural Services* (particularly leisure and recreation) stand to experience direct impacts through habitat changes and *Supporting Services* such as nutrient cycling rely on healthy ecosystem status.

The loss of coastal protection function from saltmarshes and beaches is likely as habitats reduce in area. Moller *et al.* (2001) noted that 200m of saltmarsh surface reduced wave heights up to 63%. King and Lester (1995) attributed a value to salt marshes of different width in terms of the reduced height of seawall required for flood defence (however, there is substantial uncertainty regarding the figures). Response options to loss of intertidal habitat all have different costs. To the costs of ongoing defence of landward areas by hard defences, must be added the cost of creating compensatory habitat in Natura 2000 sites and ecosystem service losses in all such sites. Intervention in the form of beach nourishment has ongoing maintenance costs while removal of the landward defences altogether to permit coastal retreat may cause loss of infrastructure and property.

A variety of recreational activities would be affected by habitat and ecosystem change (English Nature, 2002) including angling, birdwatching, wildfowling, walking, and bathing. The narrowing of beaches in front of seawalls reduces available space for beach visitors and degradation of the coastal environment through construction of defences has negative aesthetic impacts that may affect visitor preference (Ergin *et al.,* 2006). The economic value of recreational visits to nature conservation sites is illustrated by a study on the North Norfolk coast, where a survey of visitors to six nature reserves revealed local annual expenditure of £21 million that helped to support over 600 jobs (RSPB, 2000).

The health and wellbeing that arise from appreciation of natural environments and coastal recreation have received some attention (English Nature, 2002). In a study in Australia, Baumann *et al.* (1999) concluded that respondents who lived in a coastal postcode were 23% less likely to be classified as sedentary, 27% more likely to report levels of activity considered adequate for health, and 38% more likely to report high (vigorous) levels of physical activity than those who lived inland

3.3. Cultural Heritage and Archaeology

The abundance of coastal archaeological sites (underwater, in the intertidal zone, and along the coast) and cultural heritage sites (e.g. harbours, piers, jetties, quays, wrecks, harbour buildings and fisheries buildings, lighthouses, coast guard stations, and fortifications) will come under increasing risk of damage through coastal erosion and flooding. In England (Cassar, 2006, p 32) notes that 'coastal sites are under the very highest level of threat' and cites an estimate of 600-1800 'good sites' as being at risk from coastal erosion in England. Coastal fortifications are at high risk, particularly 20th century structures of non-durable materials. In Scotland, up to 10,000 archaeological sites are believed to be at risk from coastal erosion and a Trust (Scottish Coastal Archaeology and the problem of Erosion, SCAPE) has been established to address the issue (Historic Scotland, 2007).

At present, in situ-preservation is the favoured strategy for managing coastal heritage sites but increased costs will lead to the necessity of other options such as retreat, or excavation and recording. All adaptation measures have associated costs that will increase in line with increased sea levels, flood risk and erosion. Some high profile sites such as the Neolithic settlement at Skara Brae in Orkney have been defended against erosion since their discovery. At the historic site of Reculver in Kent, £1.2 million was spent in 1998 on repairs to the sea wall (www.canterbury.gov.uk/buildpage.php?id=770). At Mussenden Temple in Northern Ireland £17,000 was spent on stabilising adjacent cliffs to ensure its safety.

Alternatives, such as relocation or excavation and recording also have associated costs. In response to cliff erosion, for example, the privately owned Belle Toute lighthouse in East Sussex was moved landward at a cost between £200-300,000 (McGlashan, 2003). An increased demand for archaeological excavation is likely while a failure to meet the demand will result in the loss of sites before they are recorded.

Loss of heritage sites provokes societal concern and there is often strong local affinity for cultural heritage sites. Many historical sites are also visitor attractions and coastal icons, and there are knock-on impacts for tourism. An additional linkage is that new flood and coastal defences in response to rising sea level can cause damage to the archaeology of historic waterfronts, as well as to the character of historic quaysides and waterside buildings (English Heritage, 2006).

3.4. Tourism, recreation and leisure

Tourism is a major coastal industry that stands to be affected by changing climate. There is marked spatial variability in the importance of coastal tourism to the economy. In many rural coasts and in coastal resorts it is of particular importance. Over 3 million people live in seaside resorts in Britain. Devon and Cornwall had 21 million visitors in 2000 that spent over £3.5 billion and supported 225000 jobs, 75% of these visitors were attracted by culture and environment (SWCCIP, 2003). Large coastal cities also derive significant benefits from tourism. Tourism is the second largest sector of London's economy with 26 million staying visitors and 130 million day visitors spending £15 billion and supporting over 250,000 jobs (Evans, 2008).

Tourism is likely to be affected by direct and indirect impacts of climate change. Direct effects come from changing temperature, rainfall and wind while indirect impacts arise from coastal erosion, flooding, habitat change and impacts on cultural heritage.

Some low-lying coastal sites may become increasingly inaccessible due to rising sea level and higher frequency of extreme water levels. Parts of the Giant's Causeway (with 500,000 visitors annually), for example, is likely to become inaccessible (Orford *et al.,* 2007). At other sites armouring of eroding cliffs might stop erosion and exposure of geological strata and fossils. Such features are an important element in tourism at sites such as Dorset's "Jurassic Coast" (www.jurassiccoast.com).

Loss of beach resource is likely to be of particular concern for seaside tourism. This is likely to arise through coastal squeeze on beaches backed by seawalls or through sea defences that cut off alongshore sediment supply to coastal systems as they adjust to changes in sea level. The nature of human response to such threats will have a strong influence on the economy.

Loss of surface area will be most evident on beaches backed by seawalls. In many seaside resorts the seawall supports a promenade that has historically provided views and access to the beach. Maintaining sea defences behind narrower beaches and under increased storm surge frequency will involved increased maintenance costs and probably necessitate enhancement of the defences. Loss of recreational space accompanied by loss of environmental quality will result from such an option. If such changes reduce visitor numbers there will be economic consequences for the local economy. There are, however, many instances of the public continuing to use degraded coastal sites. At a regional scale reduced use of one site may result in displacement to others.

An alternative strategy is to nourish eroding beaches to maintain their area and viability as sea defences. This can maintain the recreational resource and associated economy but has ongoing maintenance costs and requires a suitable source of sediment for nourishment.

The landward removal of tourism infrastructure is another response option to coastal erosion. On the eroding coast of east Yorkshire the implications of moving caravan and mobile home parks landward have been assessed (Tyldesley and Associates, 2003). The parks form a significant part of the local economy and the adjacent eroding coast has nature conservation designations and forms part of an active coastal sedimentary cell. Landward movement of the parks rather than coastal defence was in line with coastal management objectives and while it would enable natural processes to continue unimpeded on the coast, it would impose significant costs. The benefits to the public from such an approach were argued to support public subsidy of the relocation (Tyldesley and Associates, 2003).

Direct climatic impacts on the tourism economy are less readily quantified than weather effects; Small tourism-related businesses claim to have observed weather-related effects. Visitor numbers to UK coastal resorts are strongly correlated with daily temperature (Agnew, 1999). Thus any increase in the frequency of warm weather would result in an increase in visitor numbers.

Nicholls and Amelung (2008) showed that under various scenarios there could be an increase in the number of what are classified in tourism terms as “very good months” in southern England from 1-3 at present to 4-6 by the end of the century. Ireland, Scotland and Wales which currently have none, could attain 2-4 “very good months”. With increasing temperatures, the Tourism Climatic Index (TCI) is becoming more favourable in North-west Europe than the Mediterranean (Amelung and Viner, 2006). This may create higher numbers of coastal visitors and users than at present and in turn is likely to precipitate calls for good quality environments (Phillips and Jones, 2006).

In the south of England (SWCCIP, Devon County Council and SECCIP, undated), the north-west (McEvoy *et al.,* 2006) and on the Sefton Coast (Fahy *et al.,* 2006), the effects of climate change on coastal tourism have been assessed. In southern England, potential effects of climate change on coastal tourism were cited (SWCCIP, Devon County Council and SECCIP, undated), as:

- A bigger tourism service economy and more jobs, but also more traffic congestion and pressure on water supplies, sewage capacity and health facilities.
- Storm damage to buildings, harbours, woodland/trees, gardens, caravan and camp sites, especially in exposed locations.
- Loss of some beaches through sea-level rise and loss of access to others due to tide cut-off.
- Coastal flooding after storms.
- Greater opportunities for water based tourism but also risks from extreme events.
- Temporary loss or closure of infrastructure - power lines, roads, rail lines, and coast paths severed by storm damage or flooding.

On the Sefton coast in the north-west, a study by Fahy *et al.* (2006) showed a strong relationship between weather and visitor choice. Road infrastructure is currently under pressure with existing traffic flows. The fact that most visitors use a car to travel to the coast mean that an increase in visitor numbers with improved future climate might exceed the current carrying capacity as determined by car parking availability as well as place additional pressure on traffic volumes. The Sefton study also considers the future for golf courses, of which many are on the coast. It noted that while opportunities are likely to arise from better summers and milder winters in the future, there would also be additional pressures. An example of both positive and negative impacts on golf courses was provided by research reported by the Scottish Golf Environment Group (Table 1).

Prediction	Positive impact		Negative impact	
	Playing quality	Agronomic effect	Playing quality	Agronomic effect
Wetter autumns/ winters	• None	• None	• Softer surfaces. • Standing water. • Green closure. • Muddy conditions. • More pitch marks. • Poorer spring condition and greater time for greens to reach summer condition.	• More compaction. • More rapid thatch accumulation. • More turf disease. • Increased sealing of surface. • Reduction in turf health. • Annual meadow-grass promotion. • Moss ingress
Milder autumns/ winters	• More play. • Longer playing season.	• Longer growing season. • More growth. • More recovery.	• More disruption to surfaces from disease scars. • More wear	• More pest and disease activity. • Greater variety of disease and more severe attacks. • More compaction. • More thatch accumulation. • More wear. • Annual meadow-grass promotion.
Drier summers	• Firmer surfaces. • More play. • More pleasurable play. • Less summer closure. • Better presentation.	• Aids promotion of fine grasses. • Slower growth. • Less thatch accumu-lation. • More rapid thatch digestion.	• Reduction in uniformity and quality of surface from drought in terms of receptiveness and trueness.	• More turf stress. • More stress on annual meadow-grass. • Greater irrigation requirement. • More signs of wear.
Less frost and snow	• Less winter green closure. • More play.	• Reduction in ice damage to turf. • Reduction in disease activity beneath snow. • Reduced risk of foot damage on frosted greens.	• More wear.	• More pest and disease activity. • Greater variety of disease and more severe attacks. • More compaction. • More thatch • Annual meadow-grass promotion.

Table 1. Projected positive and negative impacts on golf course management practices arising from climate change (Scottish Golf Environment Group, 2004)

3.5. Fishing and Aquaculture

The capture of wild marine organisms and the farming of other marine species represent an important sector of the coastal economy. The UK fishing fleet, however, reduced in size by 20% in the past ten years to 6736 vessels (MFA, 2008). Over the same period the number of fishermen fell by 32% to 12,729. Ireland had 6000 employed in fishing in 2003. Reduced catches (by tonne) of pelagic and demersal fishes have been matched by increased shellfish catches and the overall value of the total fish landed has remained practically unchanged over the past ten years (MFA 2008). UK vessels landed 610,000 tonnes of sea fish (including shellfish) in 2007, with a value of £645 million. Irish vessels produced 294,000 tonnes valued at £162 million in 2003.

The main economic impact of climate change on fisheries has been to reduce the maximum sustainable yield of cod, plaice and sole. Climate change has been estimated to have been eroding the maximum sustainable yield of cod at a rate of 32,000 t per decade since 1980 (Pinnegar *et al*., 2007). There have consequently been marked regional differences in the economic impact on UK fisheries. The Scottish fleet (dominated by demersal and pelagic fish) saw its share of the total UK catch drop from 69 to 61% between 1997 and 2007 while in England and Northern Ireland, which both had a higher proportion of shellfish, the tonnage landed increased slightly (MFA, 2008).

It is likely that as existing stocks yield lower and lower catches, new, warm water species will become exploited in the future but there is great uncertainty regarding the nature of potential future fisheries. Sweeney *et al*., (2008) report, for example, that warm-water species such as triggerfish, red mullet, red bream (red snapper), longfin tuna (albacore), eagle fish, sunfish and amberjack are already being caught in Ireland.

The economic reliance on the recent increase in shellfish landings means that ocean acidification is a particular risk to the fishing sector. A 10-25% reduction in growth/calcification due to ocean acidification (estimated to occur about 2050) would result in a 10-25% loss of shellfish landings worth £24.4 - 61 million per year and around 1000-3000 potential job losses (Turley *et al*., 2009). Acidification has similar implications for shellfish aquaculture.

In 2004, England, Scotland and Wales had 613 fish and shellfish farming businesses operating on 1329 sites, employing 3,412 people. In Ireland, 2058 people (782 full-time) were employed in aquaculture in 2006 (MERC consultants, 2007). The main finfish species farmed are salmon (139 000 tonnes mainly in Scotland) and rainbow trout (16 - 17,000 tonnes) (DEFRA, 2008). Pelleted food to supply these finfish aquaculture operations (192,000 tonnes) is at risk from ocean acidification (Turley *et al*., 2009). The total value of the UK fish meal market itself in 2004 was £81 million (European Parliament, 2004). Reduction in availability of these raw materials could therefore impact finfish aquaculture. Shellfish aquaculture in Ireland was worth €60 million in 2006. A 10-25% reduction would represent €6-15 million in lost revenue.

Warmer waters may lead to more frequent toxic algal blooms and more frequent jellyfish infestation (Sweeney *et al*., 2008). These have implications for aquaculture operations; a salmon farm in Northern Ireland containing 100,000 fish was destroyed by jellyfish in late 2007. Aquaculture is a particularly important economic activity in rural locations. Similarly, fishing is concentrated in a number of traditional fishing ports. Declines in either of these areas could have particularly strong local impacts on the economy of their local areas.

3.6. Buildings and infrastructure

There is much public concern over the impacts of coastal erosion and flooding on property and infrastructure and this is likely to increase with climate change. Some types of infrastructure (power stations, ports, sewage treatment plants) rely on a coastal location. Some have a particularly high value because of their coastal location, the latter includes buildings (hotels, private residences), public amenities (parks, promenades, swimming pools) and scenic roads and railway lines.

The UK Foresight exercise on future flooding provides assessments of the risk of terrestrial and marine flooding in England and Wales as well as coastal erosion under four climate change (high-low emissions) and linked human development (high-low economic growth) scenarios for the 2080s. Economic losses through coastal erosion (assuming the same level of expenditure on defences as at present) could increase nine-fold to £126 million/year, but there would be strong regional variability in the risk linked to both rates of relative sea-level rise and coastal geology (Figure 2). The worst affected areas are likely to be the soft coasts of the south-east and central east coast of England as well as the Severn Estuary. The number of people at risk from river and coastal flooding (they are not separated in the analysis) could increase from 1.6 million at present to 2.3 to 3.6 million by the 2080s.

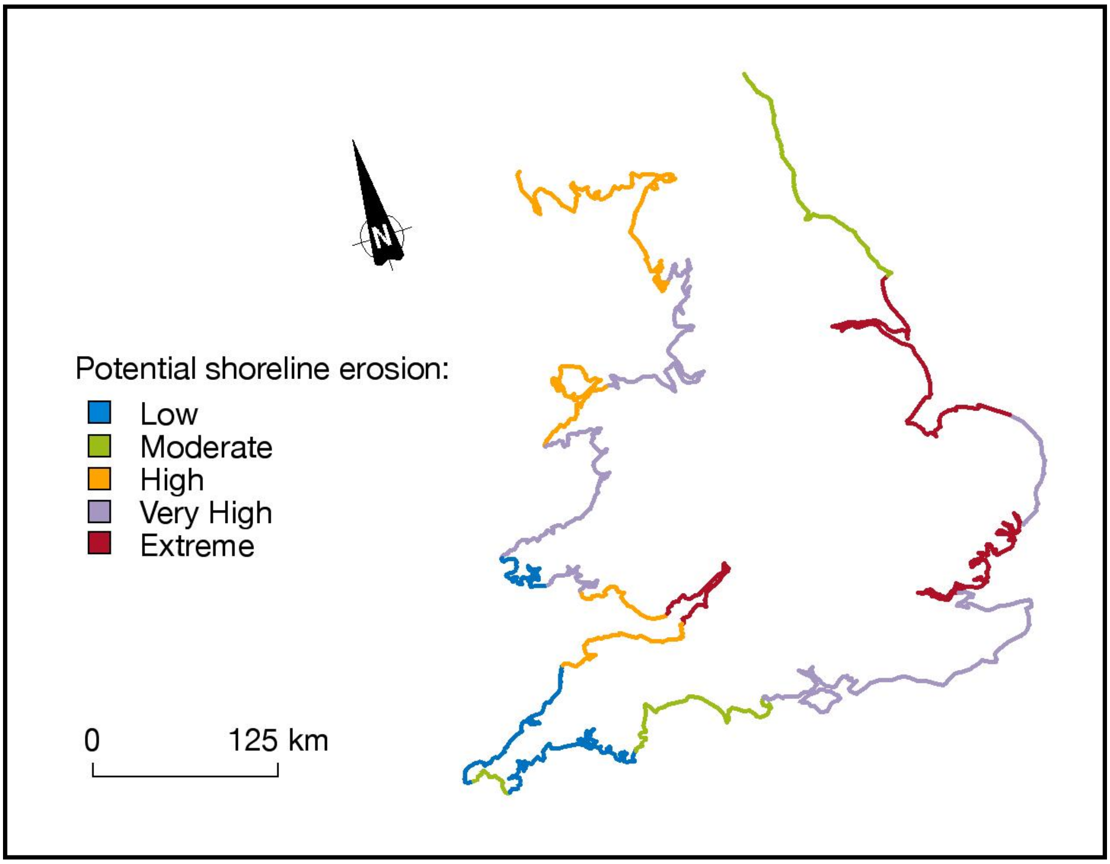

Figure 2. Distribution of coastal erosion risk in England and Wales. After Foresight (2004)

Currently about a third of the coastline of England and Wales is protected (CIWEM, 2006) compared to <4% of the Irish coast (Boelens *et al.,* 2005). If these defences are to be maintained they will require repair, augmentation and enhancement. There are also likely to be calls for new defences as property close to erodible coasts is threatened by erosion. Existing levels of expenditure on coastal defences, however, will be insufficient and approximately one-third of existing coastal defences could be destroyed.

Construction of defences has an economic cost in capital and maintenance and they have negative impacts on the natural sedimentary system, habitats and the landscape. It does benefit the engineering industry. Beach nourishment (although it maintains recreation and defence function) also has ongoing costs that will increase will sea level rise. It does bring gains for the engineering and aggregates industry.

Retreat in a managed or unmanaged way has direct implications for infrastructure that is lost and property. Increased flood risk brings increased costs of emergency preparedness.

Sea-level rise means that severe coastal floods will become more frequent and their economic impact will be greater. By way of example, in February 2002, a low pressure system in the southern Irish Sea coincided with spring high tide. This resulted in the highest recorded extreme water level in Dublin Port since records began in 1923 (Figure 3).

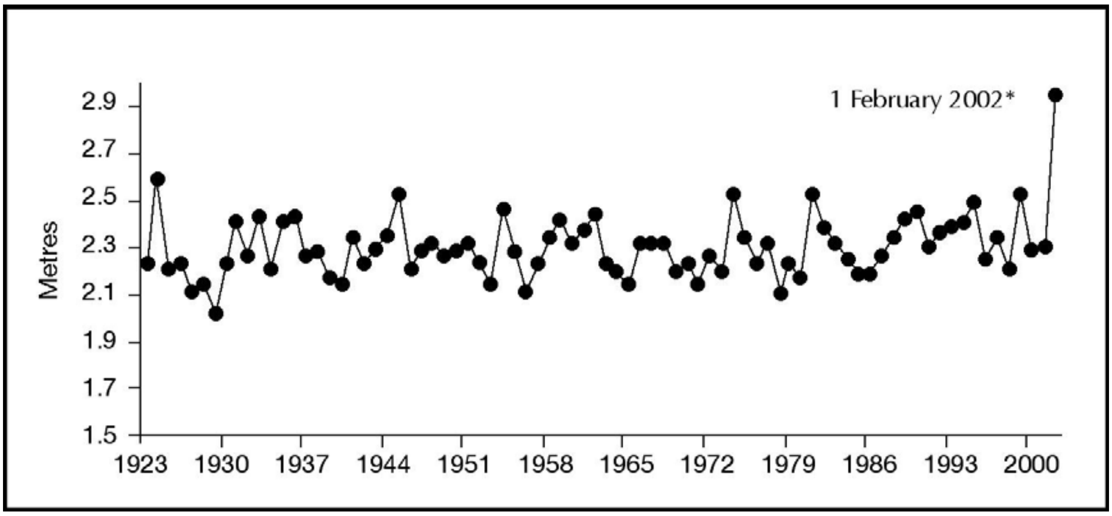

Figure 3. Annual extreme high water level, Dublin Port. From: Irish Committee on Climate Change, Third Scientific Statement. Royal Irish Academy, Dublin.

The storm surge reached 1m in Belfast and it had caused flooding and erosion along the eastern Irish Coast between Cork and Belfast. Insurance losses in the Republic of Ireland totalled €37 million (Boelens *et al.,* 2005). At Newcastle, County Down, a seawall collapsed and in Belfast, parts of the harbour estate were flooded. In the Isle of Man, Woodworth (2003) reported £4 million of damage over a three hour period as a result of the surge. Flooding occurred in Blackpool and along the western Scottish coast. The Newhaven-Dieppe ferry ran aground in heavy seas and ferry services across the Irish Sea were suspended. Wind damage caused power supply disruption from Wales to Scotland.

A rise in relative sea level of 0.5 m would mean that the extreme water level of February 2002 with its attendant impacts would become an annual event♣. Society is unlikely to accept such scales of damage on an annual basis and to adapt will require either substantial augmentation of existing sea defences, improved emergency planning measures or relocation of infrastructure.

A number of initiatives have begun to consider the implications of climate change for different elements of the coastal economy. In the Thames, for example, the Building Futures report (2007) considers the potential economic and social implications of (i) an enlarged Thames barrier near the mouth of the estuary and (ii) an approach in which the lower reaches of the estuary are left undefended. In each of these, quite different development scenarios are predicted to result. In (i) housing development is envisaged on the defended floodplain which in turn would lead to more demand for infrastructure and potential out-migration from central London as infrastructure developed. In scenario (ii) in which flooding occurred with increasing regularity innovations in building design and/or alteration of existing houses are mooted as adaptation strategies to a continued flooding risk.

♣ Editors note: This is determined by adding 0.5 m to the extreme water levels observed since 1923, as shown in Figure 3, but not taking into account any changes in the future frequency or severity of storms.

An indication of societal change is evident in the fact that the second generation of shoreline management plans (SMPs) involves a withdrawal of support for some areas that were previously defended. There is increasing pressure on coastal defence spending and a review of policy is implied in DEFRA's 'Making Space for Water' strategy for flood and coastal defence. A coastal defence policy is under development in Ireland in response to a higher awareness of flood and erosion risk.

As a large number of power stations are situated adjacent to the sea for cooling water, the future vulnerability of energy supplies needs to be considered in the context of projected future change in the coastal zone (Walsh *et al.,* 2007)

Many British and Irish ports are built on low-lying and often reclaimed land in estuaries. Increased frequency of storm surges will affect their operation and no doubt will require capital expenditure on infrastructure to cope with changed conditions.

A direct economic effect of increased flooding risk under future sea-level rise is increased insurance costs or removal of insurance. Lloyd's (2008) identified options to reduce insurance premiums as flood defence, raising buildings and flood-proofing building alterations. For a presently undefended, high-risk property in northern Europe, insurance risk would be 75% higher than present under a 30cm increase in sea level by 2030. A building that is currently defended against a 1:100 year could experience a doubling of risk under a 30cm rise in sea level.

At a regional level, major flood defences such as tidal barrages are being closed more regularly. These will need to be upgraded for future relative sea level rises if they are to continue serving a defence function. The alternatives are increased flood risk, changes in land occupation patterns or in construction methods.

Rising sea levels will also have implications for drainage which may necessitate reconstruction and redesign. "The choice of system upgrade or system replacement will require the integration of climate change research with whole life costs over a considerable time period to assess the full implications" (UKCIP, 2003, p.5).

3.7. Commerce and Businesses

Many types of business are affected by extreme weather conditions. A survey of small business directors in south-east England (Norrington and Underwood, 2008) showed that 54% had experienced weather-related impacts on their business (mostly rain or flooding) in the previous two years. The impacts were usually negative (e.g. loss of stock, damage, reduced customer numbers) but some positive influences were also noted (e.g. increased sales during hot weather). While the respondents seldom attributed such impacts to climate change, the results do show that weather events and trends do have impacts on small businesses. As the climate changes, and the frequency of occurrence of extreme conditions changes, all sectors of the economy face a "range of new threats and opportunities" (Metcalfe *et al.,* 2009 p3). These are highly uncertain and subject to many influences other than climate change.

Norrington and Underwood (2008) found that 58% of all small businesses believe that climate change will have some impact on their business. Opportunities related to climate change included the potential supply of air conditioning in a warmer environment while potential threats were also identified if customers took business elsewhere as a result of changing temperatures.

The increased insurance costs related to flood risk, or the costs of appropriate adaptation measures described above will increase the costs of doing business in coastal locations. Awareness of future climate change is, however, already having effects on business practice. The Southeast Climate Change Partnership (2005) advises that new developments should be designed to adapt to the changing climate throughout their lifetime. Its report includes guidance on adaptation of construction methods to take account of climate-related issues such as water re-use and efficiency and reducing flood risk.

3.8. Social and cultural aspects

Coastal communities are likely to experience various types and levels of social impact according to their specific circumstances. Many coastal communities in both rural and urban areas possess particular attributes derived from traditional livelihoods associated with fishing, port activities, and seaside resorts. In many cases economic and social changes have prompted major changes in these communities. Identifying purely climate change-related influences is difficult.

Small coastal communities (e.g. Happisburgh, www.happisburgh.org.uk) voice concerns about loss of community and social cohesion as a result of homes being lost through coastal erosion. In Louisiana, the uniqueness of coastal communities is often highlighted in debates regarding coastal erosion. Such communities can suffer economic loss from coastal erosion initially through blight (loss in value, loss of insurance cover) and then through actual property loss. The same effects can arise when areas are subject to repeated flooding. Communities can similarly be affected by economic conditions, several of which, as reported above, stand to be impacted by climate change.

Coastal communities based on fishing have been under pressure from various impacts including overfishing. Future changes in marine ecosystems and associated fisheries will likely have additional implications for such communities. Subsequent diversification into aquaculture, leisure and tourism (Stead, 2005) could also be affected by coastal landscape changes and aquaculture by acidification and temperature changes. These impacts on rural coastal economies would likely contribute to the rural coastal depopulation trends already observed in Scotland (Scottish Executive, 2002).

4. SUMMARY OF KEY LINKAGES

Climate change is manifest in many ways that have direct and indirect impacts on coastal economies and people. In summary, changes in sea level lead to changes in geomorphology which, in combination with oceanographic and atmospheric changes, is manifest in natural ecosystem changes. These changes have impacts on ecosystem services that in turn affect a range of human activities at the coast. The impacts on human society from this network of changes prompt responses (adaptation) which in turn affect the other changes in the system in a feedback relationship.

Attempts to quantify the economic and societal impacts of climate change at the coast are fraught with difficulty because of the uncertainties in (i) the magnitude and rate of change that is expected, (ii) the specific nature of the coastal response and (iii) human adaptation patterns. Consequently the regional and global analyses of climate change impacts on coastal communities that feature in the literature have very low levels of certainty. The nature of future impacts on coastal economies and people is highly dependent on both ongoing human adaptation strategies and socio-economic trends (Holman *et al.,* 2005). Nicholls (2004) for example, provides a simulation in which incidence of flooding initially increases but then declines with time despite accelerating sea-level rise, because of improved defence standards. In contrast, Turner *et al*. (2007) considered the economics of various adaptation strategies for the Humber Estuary with respect to both the built and natural environment. They concluded that managed realignment was economically preferable to hard defences if a sufficiently long time perspective was considered. The adaptation strategy adopted at a particular location brings additional economic impacts; adoption of hard or soft defence options could boost the engineering and construction sectors, for example.

Rising global average temperatures (high confidence) over the past century are paralleled by increases in global average sea level (high confidence), although the decadal scale variability in temperature is more pronounced than that of sea level. Global sea-level rise (high confidence) in combination with vertical land movements (moderate confidence) is producing variable rates of relative sea-level change (relative position of land and sea) around the British Isles (higher in the south then the north).

The rising sea level will have physical impacts on coastal geomorphology (high confidence) but the effects at any given location are mediated by many interacting variables and so there is low confidence in future quantitative predictions of coastline position and configuration. Coastal habitats and ecosystems will respond to changes in geomorphology and this will affect the value of ecosystem services provided. These changes, plus direct influences of temperature, rainfall and wind patterns will affect the coastal economy of the British Isles in various ways through their impact on ecosystem services. Because the effects are transmitted via a complex web of interactions and are mediated by ongoing adaptation measures, there is low confidence in predictions of future impacts other than at the general level.

Defence of property inevitably leads to environmental degradation and habitat loss (high confidence), with capital and maintenance costs accruing to present and future generations (high confidence). Retreat, while preserving the functioning of the coastal ecosystem, involves loss of property with costs to present infrastructure owners. Any increase in frequency of damaging events (floods, storms, erosion) will inevitably be accompanied by an increase in insurance premiums or even an inability to acquire insurance which have implications for business at the coast. Adaptation measures of whatever kind have an associated cost and these costs depend on the timescale considered. Adaptation strategies at the regional level (e.g. Turner *et al.,* 2007) involve multi-sectoral considerations.

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