



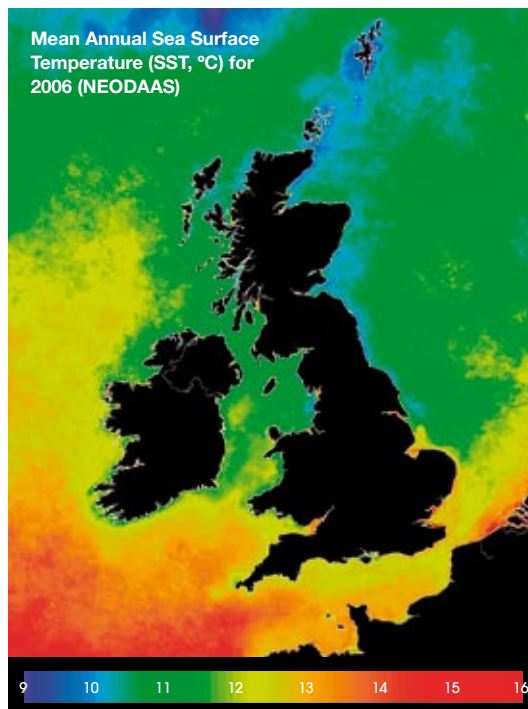
Marine climate change impacts

Annual Report Card 2007–2008

This report card builds upon the evidence base presented in 2006, highlighting key developments and exploring new subject areas (coastal erosion, coastal habitats and air-sea exchanges of heat and water). It brings together scientific understanding from a wider range of research institutes, providing an even more comprehensive assessment of UK marine climate change impacts and highlighting regional variations where possible.

“Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures”

Intergovernmental Panel on Climate Change (IPCC) 2007, Joint Nobel Peace Prize winners



Here are just some of the key findings reported in the 2007–2008 card

2006 was the second-warmest year in UK coastal waters since records began in 1870; seven of the 10 warmest years have occurred in the last decade.

Models predict fewer storms but there will be a greater number of more severe storms.

Coastal erosion is expected to increase. Currently, it affects 17% of the UK coastline.

Warmer winters have been strongly linked to reduced breeding success and survival in some seabird populations.

Introduction

As the evidence base continues to build, it is clear that marine climate change is having important impacts on the marine environment and the goods and services it provides. The information presented this year demonstrates the important knock-on effects that climate change can have through the food chain. For example, at the bottom, warming has led to plankton shifts, which have had an impact upon predators such as fish, which then affects seabirds.

Each topic includes a confidence rating for what is happening now and what could happen in the future:

HIGH CONFIDENCE

MEDIUM CONFIDENCE

LOW CONFIDENCE

Where possible, regional impacts are highlighted.

The online version of this report card (www.mccip.org.uk/arc) is backed up with full peer-reviewed reports for each topic and includes a glossary of technical terms.

Climate of the marine environment

Ocean climate is largely defined by its **temperature, salinity, ocean circulation** and the **exchange of heat, water and gases (including CO₂)** with the atmosphere. The functioning of our **marine ecosystem** is highly dependent on changes to both **ocean climate** and

acidification, whilst storms and waves, sea-level rise and coastal erosion pose clear threats to human life, **built structures and shipping**.

The bold text (below and opposite) indicates new information for the 2007–2008 report.

WHAT IS ALREADY HAPPENING

Temperature (air and sea)

BADC; FRS;
MOHC; NOCS;
SAMS; UKCIP

HIGH CONFIDENCE

- Marine air and sea surface temperatures (SST) have been rising at a similar rate to land air temperature, but with strong regional variations. Since the 1980s the rate of rise has been about 0.2–0.6 °C per decade.
- **Warming has been faster in the English Channel and southern North Sea than within Scottish continental shelf waters.**
- **2006 was the second-warmest year in UK coastal waters since records began in 1870; seven of the 10 warmest years have occurred in the last decade.**
- Recent warming is also evident in waters of the upper 1,000 m of the North Atlantic.

Storms and waves

ERI

HIGH CONFIDENCE

- **A greater incidence of severe winds and larger mean wave heights in western and northern UK waters are being observed.**

Sea level

Defra; MOHC;
POL

HIGH CONFIDENCE

- Global average sea level has risen during the 20th century by between 1 and 2 mm per year. The latest published satellite measurements suggest the rise was around 3 mm per year between 1993 and 2003.
- **Smaller rates of rise are seen in Scotland compared to the south of England.**
- **Extreme water levels have also increased in the UK, most likely as a consequence of mean sea-level rise.**

Acidification

PML

HIGH CONFIDENCE

- The ocean is becoming more acidic as increasing atmospheric carbon dioxide (CO₂) is absorbed at the sea surface. Models and measurements suggest that surface pH has decreased by 0.1 pH unit since 1750.
- **The surface ocean has absorbed nearly half of the increased CO₂ emissions due to burning of fossil fuels over the last 250 years, thus reducing the amount remaining in the atmosphere.**

WHAT COULD HAPPEN

HIGH CONFIDENCE

- Climate change models indicate that SST will continue to rise in all waters around the UK coast, with stronger warming in the south-east (~0.15–0.4 °C per decade in the southern North Sea) than the north-west (~0.05–0.2 °C per decade at Rockall).

LOW CONFIDENCE

- **Models predict overall fewer Atlantic depressions crossing to UK waters but there will be a greater number of deep depressions (intense storms) and associated increased wave heights.**

LOW CONFIDENCE

- During the 21st century a global average sea-level rise of between 9 and 88 cm relative to 1990 has been predicted **but there is uncertainty in ice-melt and its effect on the upper limit of sea-level rise; thermal expansion will account for the majority of the overall rise.**
- The anticipated range of relative sea-level rise by the 2080s (relative to the 1961–1990 mean) is 20–80 cm in south-west England and 0–60 cm in Scotland.

MEDIUM CONFIDENCE

- **Continued acidification will reduce the ability of the ocean to take up CO₂ from the atmosphere, which will have feedbacks to future climate change, further accelerating the accumulation of CO₂ in the atmosphere.**
- **Future increases in ocean acidity will have major negative impacts on some shell/skeleton-forming organisms within this century.**

WHAT IS ALREADY HAPPENING

Gulf Stream and Atlantic Heat Conveyor

NOCS

LOW CONFIDENCE

- The Atlantic Heat Conveyor (within which the Gulf Stream plays a role) helps to maintain relatively mild temperatures in north-west Europe. Some observations suggest that the Atlantic Heat Conveyor has reduced in strength by up to 30% since the early 1990s. **More data are needed to distinguish this trend from natural variability, which has recently been shown to be large on a day-to-day basis.**

Salinity

FRS; IMGL;
NOCS; SAMS

MEDIUM CONFIDENCE

- **Surface waters to the north and west of the UK have become relatively more saline since the 1970s. There are no clear trends in the shallow coastal waters of the Irish Sea, southern North Sea and western Scotland.**
- Deep waters of the North Atlantic have freshened over the past 40 years.

Shelf sea stratification and the spring bloom

Cefas; POL

MEDIUM CONFIDENCE

- **There is evidence to suggest a recent trend towards stratification (layers of less dense water above more dense water) earlier in the year, resulting in earlier spring blooms of plankton – largely in response to warming air temperatures.**

Coastal erosion

Plymouth
University

HIGH CONFIDENCE

- Coastal erosion is occurring along 17% of the UK coastline (30% of England's coastline; 23% Wales; 20% Northern Ireland; 12% Scotland).
- Almost two-thirds of the intertidal profiles in England and Wales have steepened over the past 100 years.
- Steepening of the intertidal profile is particularly prevalent on coasts protected by hard engineering structures (this represents 46% of England's coastline; 28% Wales; 20% Northern Ireland and 7% Scotland).

Air-sea flux of heat and water

NOCS

LOW CONFIDENCE

- The exchange of heat and water between the ocean and the atmosphere plays an important role in driving the circulations of both the atmosphere and ocean.
- There is little evidence for major changes in air-sea fluxes of heat and water around the UK.

WHAT COULD HAPPEN

LOW CONFIDENCE

- **It is very likely that the Atlantic Heat Conveyor will slow during this century, but not sufficiently to completely offset warming across the UK.**
- There is considered to be less than a 10% chance of a collapse of the Atlantic Heat Conveyor this century.

LOW CONFIDENCE

- Climate-driven changes in precipitation, evaporation, ocean circulation and ice-melt might influence salinity.

LOW CONFIDENCE

- Changes to rainfall seasonality and extreme events may change stratification in areas of freshwater influence, such as estuaries.
- **Stratification and spring blooms of plankton in our shelf seas will occur earlier in a warmer climate.**

LOW CONFIDENCE

- Both coastal erosion and steepening of intertidal profiles are expected to increase in the future, due to the effects of sea-level rise and changes to wave conditions.

LOW CONFIDENCE

- The global water cycle is likely to intensify but the effect of this change within the UK is uncertain.



Climate change: impacts on our vision for a healthy and biologically diverse marine ecosystem

As the **marine ecosystem** is highly interconnected through predator–prey relations, the direct impacts of ocean climate change have ‘knock-on’ effects through the food chain. For example, recent warmer conditions and associated shifts in **plankton** abundance and

geographical distribution have led to reduced availability of prey **fish** for some **seabirds**, which has been strongly linked to recent poor breeding success and reduced survival rates.

The bold text (below and opposite) indicates new information for the 2007–2008 report.

WHAT IS ALREADY HAPPENING

Plankton

FRS;
SAHFOS

MEDIUM CONFIDENCE

- A 1,000-km northward shift of warmer-water plankton, with a similar retreat of colder-water plankton, has been observed in the north-east Atlantic over the past 50 years, as the seas around the UK have become warmer.
- **In the North Sea, the population of the previously dominant and important cold-water zooplankton species *Calanus finmarchicus* has declined in biomass by 70% since the 1960s.**
- **The seasonal timing of plankton production has altered in response to recent climate changes. Some species are occurring up to four to six weeks earlier than 20 years ago, affecting predators, including fish.**

Fish

Cefas; FRS;
MBA

MEDIUM CONFIDENCE

- Abundances of warm-water fish species (e.g. red mullet, John Dory, triggerfish) have increased in UK waters during recent decades, while many cold-water species have experienced declines.
- **There has been a notable influx of snake pipefish to UK waters since 2004, and research is under way to explain this.**
- **Poor ‘recruitment’ of juvenile cod may be associated with a climate-related shift in the composition of zooplankton, but also by a reduction of the adult, parental population by fishing.**
- **In some parts of the southern North Sea, cold-water species, such as cod and eelpout, have been shown to experience metabolic stress during warm years, as evidenced by slower growth rates and difficulties in supplying oxygen to body tissues.**

Marine mammals

Sea Watch
Foundation;
SMRU;
University of
Aberdeen

LOW CONFIDENCE

- **The impact of climate change on marine mammals (i.e. seals and cetaceans) remains poorly understood.**
- **Range shifts have been observed in a number of cetacean species, but at present it is not possible to differentiate between short-term responses to regional resource variability and longer-term ones driven by climate change.**

Seabirds

CEH; JNCC

MEDIUM CONFIDENCE

- Poor breeding success and reduced survival of black-legged kittiwakes in recent years have been strongly linked to warmer winters and changes to their fish prey populations (e.g. smaller, less-nutritious sand eels, increased snake pipefish abundance). Other seabird species may have been similarly affected.

Non-natives

FRS;
SAHFOS;
University of
Cambridge

MEDIUM CONFIDENCE

- Distributions of non-native species are currently limited by water temperature.
- Non-native marine organisms (e.g. japweed and Chinese mitten crab) are spreading and becoming established in our waters through a combination of climate change, migration and human introduction. These can cause major ecological changes.

WHAT COULD HAPPEN

LOW CONFIDENCE

- Continued increase in sea temperature, due to climate change and associated changes such as ocean acidification, are likely to exert major influences on plankton abundance and geographical distributions, with implications for primary production and climate control.

LOW CONFIDENCE

- **Climate change will have far-reaching impacts on the dynamics of fish populations; however, current knowledge of underlying mechanisms is limited.**
- **Much less is understood about the possible future impacts of climate change on non-commercial fish species, compared to those targeted by fisheries.**

LOW CONFIDENCE

- Marine mammals may suffer impacts from changes affecting the food chain that supports them.

LOW CONFIDENCE

- **Some species will have difficulties in adapting to changing prey availability.**
- **Long-term climate change will result in a northwards shift in the range of some species and consequently a decline in UK population size.**
- Anticipated sea-level rise and a greater number of more severe storms may reduce available breeding habitat for shoreline-nesting species (e.g. terns) and wash away nests.

HIGH CONFIDENCE

- Future temperature increases could enable more species to invade and become established, replacing current native species.

WHAT IS ALREADY HAPPENING

Intertidal species

MBA; SAMS

MEDIUM CONFIDENCE

- Some warm-water invertebrates and algae show continued increases in abundance and have extended their ranges around northern Scotland and eastwards along the English Channel over the last 20 years.
- The warm-water seaweed *Bifurcaria bifurcata* has established a new range boundary at Portland Headland in the last five years, 150 km east of previous records.
- Cold-water species (e.g. the acorn barnacle and dabberlocks alga) have continued to decrease in abundance throughout the period 2001–2007.

Seabed ecology

FRS; Liverpool University

MEDIUM CONFIDENCE

- Climatic processes influence the abundance and species composition of seabed communities, directly affecting the availability of food for bottom-feeding fish.
- Localised effects of fishing, causing habitat modification, and of contaminants are also important and make it difficult to fully assess the scale of the influence of climate change.

Coastal habitats

University of Cambridge; University of Southampton

MEDIUM CONFIDENCE

- Coastal habitats are being lost around the UK. In England, it is estimated that at least 40–100 hectares of saltmarsh is being lost every year; projects are under way to estimate rates of loss in other regions.

WHAT COULD HAPPEN

MEDIUM CONFIDENCE

- Projected changes in sea level and storms may have important indirect impacts, as more sea defences are required. These act as artificial rocky shores allowing intertidal species to unnaturally extend their range.
- Continued extension and retraction of ranges within the UK, with rising temperatures of southern and northern species respectively.
- Some new species will become established, whilst others will disappear from our shores.

LOW CONFIDENCE

- Changes to sea temperature and/or food supply are likely to continue to alter the ecological structure of the seabed.

LOW CONFIDENCE

- Coastal habitat loss will be accelerated by sea-level rise.



Climate change: impacts on our vision for clean and safe seas

Sea-level rise will lead to more **coastal flooding** with impacts on **coastal erosion, coastal habitats, built structures** and possible threats to human life. Links between land and sea are also strongly expressed in contaminant transport (**nutrients** and other **pollutants**), as their seaward

transport will be highly dependent on future climate change on land (e.g. drier summers with episodic downpours; a greater number of more severe storms).

The bold text (below) indicates new information for the 2007–2008 report.

WHAT IS ALREADY HAPPENING

Coastal flooding

Defra; MOHC; University of Southampton

LOW CONFIDENCE

- Increased flood risk, from both rivers and the sea, is **one of the most significant predicted impacts of climate change in the UK.**
- An increasing trend in extreme water levels has been observed and is most likely to be a consequence of the rise in average sea level.

Nutrient enrichment

Cefas; FRS; NOCS

LOW CONFIDENCE

- Drier summers may be contributing to a decrease in nutrient inputs in European seas.
- It is difficult to discriminate between the effects of human inputs (e.g. agricultural run-off) and those that may be due to climate change through rainfall and ocean transport.

Harmful Algal Blooms (HABs)

Cefas; FRS; NUI Galway; SAHFOS

MEDIUM CONFIDENCE

- **Harmful Algal Blooms (HABs) – harmful due to the release of toxins and sometimes by oxygen depletion – are now thought to be driven largely by ocean climate forcing, with nutrient enrichment only relevant to some cases.**
- HABs have increased in some areas of the north-east Atlantic over the past 50 years, as the seas around Great Britain and Ireland have become warmer, especially since the mid-1980s.
- There is regional variability within this trend and some places, such as the east coast of Britain, have experienced reduced incidences of HABs.

Pollution

Cefas

LOW CONFIDENCE

- Unknown. Pollutant monitoring is currently inadequate for identifying climate change related impacts.

WHAT COULD HAPPEN

LOW CONFIDENCE

- Further rises in sea level over the next 100 years will tend to increase the frequency of extreme high-water-level events.
- **Future changes in storminess may alter the frequency of extreme high-water-level events, but the precise effects are uncertain and will depend on location.**

LOW CONFIDENCE

- Drier summers may decrease nutrient inputs, although sudden storms may deliver pulses with consequences that are difficult to predict.
- More intense winter storms will raise concentrations of nutrients at the ocean surface and may increase transfer of nutrients into shelf seas.
- If summer stratification (reduced mixing) becomes stronger, nutrient supply to surface waters will reduce during the productive seasons.

MEDIUM CONFIDENCE

- Rising temperatures and reduced mixing of the water column (increased stratification) would favour many HAB-causing species. **Susceptible regions, such as the eastern Irish Sea and some estuaries, are also thought to be vulnerable to elevated nutrient concentrations.**
- **The direct effects of storms (decreasing stability, lower light levels) and associated nutrient pulses are less predictable and may favour some HAB species over others.**

LOW CONFIDENCE

- Climate change may influence the release of pollutants currently locked in seabed sediments.
- Terrestrial inputs of storm water containing untreated sewage and other pollutants may increase.



Climate change: impacts on our vision for commercially productive seas

The impacts of climate change on the commercial services provided by our seas will be significant. **Sea-level rise, coastal flooding and storms and waves** will affect ports, **shipping** and **built structures**. **Fishing and fish farming** will be affected by **temperature change and plankton**

availability. Rising temperatures should have positive impacts on **tourism**, whilst retreating Arctic sea-ice may open up new (seasonal) **shipping routes**.

The bold text (below) indicates new information for the 2007–2008 report.

WHAT IS ALREADY HAPPENING

Shipping

Plymouth University

LOW CONFIDENCE

- There are no academic studies available on the direct impacts of climate change on shipping, although numerous industry and media reports have been published in the past year.
- Climate change mitigation measures are having an indirect impact; in the short term, regulation of greenhouse emissions will arise through international agreement and a Greenhouse Gas Indexing Scheme for ships is being developed.
- Fuel efficiency and reduction of greenhouse gas emissions are driving a push for new propulsion and hull technology.

Tourism

NE; University of Maastricht

HIGH CONFIDENCE

- Climate change is increasing the frequency of months when conditions are more comfortable for tourists in north-west Europe than in the Mediterranean.

Built structures

Cefas

LOW CONFIDENCE

- Allowances for annual rates of sea-level rise are made in the planning of coastal structures.
- Increases in wave heights over the period 1973–1998 are part of the statistical measures that set the design criteria for oil and gas rigs.

Fisheries

Cefas; FRS; MBA

MEDIUM CONFIDENCE

- Excessive fishing pressure over many decades may have resulted in fish populations less able to 'buffer' against occasional poor year classes and the impacts of natural climate variability.
- Distribution shifts and modifications of fish behaviour as a result of temperature changes, may be affecting the vulnerability of certain fish stocks to fishing fleets.

Aquaculture (fish and shellfish farming)

FRS

LOW CONFIDENCE

- In the short term, climate change is unlikely to have a significant effect on UK-farmed marine fish (over 99% of which are cultivated in Scotland) and shellfish (39% in England and Wales; 43% in Northern Ireland; 18% in Scotland for 2006).

WHAT COULD HAPPEN

LOW CONFIDENCE

- Major risks to ports are likely to arise from flooding and physical damage associated with sea-level rise and severe storms.
- Future changes in wind speed and storminess could lead to reduced loads, route changes and restrictions for some ships.
- Continued decline of Arctic sea-ice could extend accessibility to high-latitude shipping routes, for example increasing the Arctic navigation season from Europe to Asia from 20–30 days to 90–100 days per year within this century.

LOW CONFIDENCE

- A longer tourist season and increased visitor numbers to the north-west European coastal zone will lead to: increased tourist infrastructure (i.e. hotels, attractions, marinas); increased revenues; increased employment; increased waste (i.e. sewage, solid waste); and increased environmental damage.

LOW CONFIDENCE

- Increasing rates of erosion under existing scenarios of climate change could increase damage to coastal structures by three to nine times within this century.
- The cabling infrastructure around wind farms may be particularly sensitive to changes in the supply and movement of sediment.

MEDIUM CONFIDENCE

- In the short term, climate change will have little influence on fish stock recovery, which depends instead upon reducing fishing effort to allow existing year classes to survive to maturity.
- Long-term climate change may affect the overall productivity of fish stocks in a given area. Some species may be adversely affected leading to reductions in sustainable yield whilst others, for example seabass, red mullet and John Dory, may be positively affected leading to enhanced fishing opportunities.

LOW CONFIDENCE

- Rising water temperatures could increase growth rates for some species (e.g. Atlantic salmon, mussels and oysters), but may also cause thermal stress for cold-water species (e.g. cod and Atlantic halibut) and intertidal shellfish (e.g. oysters).
- New species (e.g. sea bass, bream) may be cultivated.
- Farmed species may become more susceptible to a wider variety of diseases as temperatures increase.
- Increasing harmful algal and jellyfish blooms may lead to additional fish kills and closure of some shellfish harvesting areas.
- Increased temperatures and more abundant plankton could also improve reproduction and settlement of 'spat' at shellfish farms.

ARC Online and more information ...

To access the full topic reports, which include detailed supporting evidence and sections on knowledge gaps, commercial impacts and confidence assessments, go to www.mccip.org.uk/arc

What is MCCIP?

MCCIP is a partnership between scientists, government, its agencies and NGOs. The principal aim is to develop a long-term multidisciplinary approach to understanding and communicating the implications of climate change in our seas.

Sponsoring partners are:
Countryside Council for Wales, Defra, Dept. of the Environment Northern Ireland, Environment Agency, Natural England, RSPB, Scottish Environment Protection Agency, Scottish Government, Scottish Natural Heritage, States of Guernsey, States of Jersey, Welsh Assembly Government, WWF.
(More partners welcomed.)

Quality Assured Science

The MCCIP Steering Group (SG) consists of the sponsoring partners together with scientific experts from SAHFOS, Climatic Research Unit (CRU), MECN, FRS, Natural Environment Research Council (NERC) 'RAPID' programme and Cefas.

The SG commissioned the contributing scientists and appointed an 'Expert Advisory Panel' who peer-reviewed the quality of the science in the ARC.

List of Contributors

British Atmospheric Data Centre (BADC)
J Hill

Cefas S Dye; L Fernand; P Larcombe; M Longshaw; D Mills; J Pinnegar; J Rees; D Sheahan

Centre for Ecology and Hydrology (CEH)

M Frederiksen

Defra K Hardy

Environmental Research Institute (ERI),

Thurso J Coll; D Woolf

Fisheries Research Services (FRS)

E Bresnan; I Bricknell; M Heath; S Hughes; M Gubbins; T McCollin; D Moore

Isle of Man Government Laboratory

(IMGL) T Shammon

Joint Nature Conservation Committee

(JNCC) I Mitchell

Liverpool University C Frid

Marine Biological Association (MBA)

S Hawkins; N Mieszkowska; P Moore; D Sims

Marine Environmental Change Network

(MECN) M Frost

Met Office Hadley Centre (MOHC)

J Kennedy; J Lowe

National Oceanography Centre,

Southampton (NOCS) D Berry;

S Cunningham; S Gardiner; S Hanson;

NP Holliday; D Hydes; S Josey; E Kent;

R Marsh; R Nicholls; M Yelland

Natural England (NE) D Viner

National University of Ireland (NUI)

Galway R Raine

NERC Earth Observation Data

Acquisition and Analysis Service

(NEODAAS)

Proudman Oceanographic Laboratory

(POL) K Horsburgh; J Sharples;

P Woodworth

Plymouth Marine Laboratory (PML)

C Turley

Plymouth University

G Masselink; P Russell; P Wright

Sea Mammal Research Unit (SMRU)

I Boyd

Sea Watch Foundation (SWF)

P Evans

Sir Alister Hardy Foundation for Ocean

Science (SAHFOS) PC Reid; M Edwards

The Scottish Association for Marine

Science (SAMS) M Burrows; T Sherwin

UK Climate Impacts Programme (UKCIP)

University of Aberdeen C MacLoed

University of Cambridge P Elliott;

D Freiss; T Spencer

University of Maastricht B Amelung

University of Southampton S Gardiner;

S Hanson; R Nicholls



**Marine Climate Change
Impacts Partnership**

www.mccip.org.uk/arc

What's new for 2008

The next set of UKCIP climate scenarios (UKCIP08) will be published in 2008 and MCCIP will have a key role to play in the marine scenarios report.

www.ukcip08.org.uk

Your feedback

To help us understand if we are meeting your needs we need your views. Our short online questionnaire provides you with the opportunity to help shape future report cards and other MCCIP products. Go to

www.mccip.org.uk/arc/survey

Further details and contacts

Further details on the work of MCCIP, or on becoming a sponsor, can be found on our website: www.mccip.org.uk
If you have any further enquiries please contact us at office@mccip.org.uk

Please cite this document as: MCCIP. (2008). Marine Climate Change Impacts Annual Report Card 2007–2008. (Eds. Baxter JM, Buckley PJ and Wallace CJ), Summary Report, MCCIP, Lowestoft, 8pp.