MCCIP Marine Climate Change Impacts Partnership

# Marine climate change impacts

## Annual Report Card 2010-2011

2010-2011

www.mccip.org.uk/arc

The 2010-2011 MCCIP Annual Report Card provides the very latest updates on how climate change is affecting our seas. Almost 100 scientists from 40 leading UK science organisations contributed to this report card, making it our most comprehensive to date. New topics on air-sea carbon exchanges, deep sea habitats, waterbirds and human health are introduced, along with a UK regional seas impact map. This report card also takes a first look at how the UKCP09 climate projections might aid our understanding of future marine climate change impacts.

'Healthy oceans matter and they matter because they are vital to our health, to our prosperity, to our security, and also to our ability to adapt to climate change'

*Dr Jane Lubchenco, US Under Secretary of Commerce for Oceans and Atmosphere and Administrator of NOAA.*

### Here are just some of the new findings in the 2010-2011 Annual Report Card

© Matt Parsons, JNCC

Temperatures are generally increasing, but inter-annual variability is high; 2008 UK coastal sea surface temperatures were lower than the 2003-2007 mean.

Some fish distributions have moved northwards over the past 30 years by distances ranging from around 50 to 400km, with coldwater species such as monkfish and snake blenny moving the furthest.

Climate change has contributed to a decrease by approximately 9% in the total number of seabirds breeding in the UK between 2000 and 2008. Breeding success has also declined over the same period.

Increasing sea temperatures may have the potential to increase the geographic range of some harmful algal bloom species associated with Paralytic Shellfish Poisoning (PSP) events.

## Introduction

The 2010–2011 Annual Report Card provides an update on scientific understanding of climate change impacts on our seas. As in previous report cards, changes in ocean climate set the context for evidence of impacts on biologically diverse, clean and safe, and commercially productive seas.

Since the last full MCCIP report card was published in 2008, and the Ecosystem Linkages Report Card in 2009, there have been some significant advancements in knowledge, both for 'what is already happening' (e.g. an emerging picture of how variable the Atlantic heat conveyor is on short timescales) and 'what could happen' in the future (e.g. identification of future changes to the distribution of some species of fish).

### 'UK State of Seas reporting' and MCCIP

The *Charting Progress – An Integrated Assessment of the State of UK Seas* report in 2005 led to the formation of MCCIP, which is now well established as the primary UK tool for communicating marine climate change information. The second State of UK Seas report (*Charting Progress 2*) has drawn heavily on MCCIP expertise, including the compilation of the climate change chapter. The chapter brings together evidence of climate change impacts to date and also considers future impacts in relation to updated climate change projections.

© Sue Hiscock JNCC.gov.uk

## Topic changes since the 2007-2008 MCCIP Annual Report Card

There are some changes to the topics in the 2010-2011 Annual Report Card which are as follows:

Four new topics: air-sea exchanges of $CO_2$, deep-sea habitats, waterbirds, and human health (vibrios).

A re-structure of the 'habitat' topics covered in the biologically diverse section, to bring more into line with Charting Progress 2 reporting (the habitats covered now are 'coastal'; 'intertidal'; 'shallow and shelf subtidal'; and 'deep sea').

## Regional snapshots of marine climate change impacts

For this report card, MCCIP has adopted the *Charting Progress* sub-divisions of UK waters to provide a stronger emphasis on regional issues, and to maintain consistency with *Charting Progress* reporting. Regional climate change snapshots for what is already happening, and what could happen in the future, are included to highlight some key differences by *Charting Progress* regions (see pages. 6–7). Some of the topic headline messages also refer to these regions explicitly and many of the detailed topic reports provide more detailed information on marine climate change impacts by *Charting Progress* regions.

Wherever a topic is referred to in the regional snapshot map on pages 6–7, a UK map symbol appears next to that topic.

## UKCP09 climate change projections

UKCP09 is the most recent suite of UK climate change projections, which has significantly enhanced its consideration of marine and coastal environments.

It includes projections of changes in air-temperature over the sea, projected future sea-level rise, sea temperature, salinity, stratification and circulation, as well as surges and waves.

MCCIP co-authored the marine and coastal projections report and provided advice on user requirements for the marine scenarios. MCCIP also has a webpage about the projections (www.mccip.org.uk/projections) which includes MCCIP briefing notes on UKCP09.

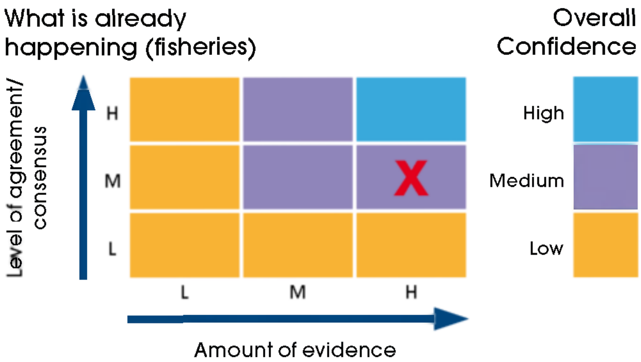
Contributors to this year's annual report card have considered these projections when summarising future impacts.

These projections have also been used to produce the regional charts of sea surface temperature change (see pages 6–7).

## Confidence assessments

Contributing authors were asked to consider the level of confidence in the science for 'what is already happening' and 'what could happen in the future' for their specialist topics.

Authors were asked to mark an 'X' in the following grid to indicate the current level of confidence in the science, based on 'level of agreement / consensus' and the 'amount of evidence available' (see below for an example from the fisheries topic for 'what is already happening'):




In each of the full, peer-reviewed topic submissions, a rationale is provided explaining why the authors have assigned a low, medium or high level of confidence.

It is important to note that the confidence assessments are for each topic taken as a whole rather than for the specific headlines included in this summary report card.



## Changes in confidence since the 2007–2008 Annual Report Card

Changes in the overall level of confidence since the 2007-2008 Annual Report Card are shown as arrows within the confidence bars for each topic.

**High Confidence** ↑
**Medium Confidence** ↓
**Low Confidence** ↔

**Each rating has an arrow to indicate whether there is an increase, decrease or no change in confidence.**

Confidence may go up or down due to new data and model outputs becoming available or through changes in understanding of the science.

The majority of confidence ratings have stayed the same since 2007-2008. However, nine have gone up, whilst six have gone down.

## 2009 MCCIP Ecosystem Linkages Report Card

The 2009 MCCIP Ecosystem Linkages Report Card looked at five key issues ($CO_2$ and ocean acidification, Arctic sea-ice loss, seabirds and food webs, non-native species, and coastal economies) to show how the interconnected nature of the marine ecosystem magnifies the many discrete impacts of climate change, documented in the MCCIP Annual Report Cards.

Please go to www.mccip.org.uk/elr to access both the summary document and the full peer reviewed reports from leading marine climate scientists.

## Knowledge gaps

As part of this year's submission, topic authors were asked to provide information on key knowledge gaps. Some of these knowledge gaps made it into this year's headline messages and all of the detailed topic reports include a section on knowledge gaps. MCCIP intends to build on this wealth of information from around 100 leading scientists, and independently verified by 30 specialist reviewers, to produce a stand-alone knowledge gaps report in the near future.

# 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 $CO_2$) 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.

To access the full peer reviewed reports, go to: **www.mccip.org.uk/arc/marine**

Where headline messages under each topic are new for 2010-2011, they are highlighted in bold text. Arrows show change in confidence since the 2007-2008 MCCIP Annual Report Card. Where a topic is referred to in the 'regional snapshot' map, a map symbol appears.

| | WHAT IS ALREADY HAPPENING | WHAT COULD HAPPEN |
|---|---|---|
| **Temperature (Air and Sea)** *Marine Scotland; NOC; Cefas; IMGL; MOHC; PML; SAMS* | **High Confidence** ↔<br>• Marine air and sea surface temperatures have risen over the north-east Atlantic and UK waters in the last 25 years.<br>• The largest increase in air temperature has been over the southern North Sea at a rate of around 0.6° C per decade.<br>• The largest increases in sea surface temperature have occurred in the eastern English Channel and the southern North Sea at a rate of between 0.6 and 0.8° C per decade.<br>• **Although temperatures are generally increasing, inter-annual variability is high. 2008 UK coastal sea surface temperatures were lower than the 2003–2007 mean.** | **Medium Confidence** ↓<br>• **Models project that temperatures will continue to rise in UK and north-eastern Atlantic waters up until at least the 2080s. However, in the next 10 years, natural oceanic and atmospheric variability make it difficult to predict whether temperatures will go up or down.** |
| **Storms and Waves** *ERI; NOC* | **Medium Confidence** ↓<br>• **Natural variability in wave climate is large and the role of anthropogenic influence is unclear.**<br>• Increases in monthly mean and maximum wave height in the north-eastern Atlantic occurred between 1960 and 1990; however, this rise in wave height may be part of long-term natural variability. There has been no clear pattern since 1990. | **Low Confidence** ↔<br>• **There is no consensus on the future storm and wave climate for north-western Europe, since projected future storm track behaviour varies among atmospheric models.**<br>• **Predictions of storm behaviour used by the UKCP09 wave model show storm tracks moving south, resulting in lower wave heights to the north of the UK and slightly larger wave heights in some southern regions, especially the south-west.** |
| **Sea Level** *NOC; MOHC* | **High Confidence** ↔<br>• Global sea level has risen at a mean rate of 1.8mm per year since 1955. From 1992 onwards a higher mean rate of 3mm per year has been observed.<br>• **Sea-level rise measured over the UK is consistent with the observed global mean.** | **Medium Confidence** ↑<br>• Projections of change in the UK suggest a rise of between 12 and 76cm by 2095, compared to a 1980–1999 baseline. This approximately equates to rates of between 1.2 and 7.6 mm per year respectively.<br>• Considering projected land movements, a greater rise in southern regions of the UK is likely relative to the north. |
| **Ocean Acidification** *PML; Bristol University; MBA* | **High Confidence** ↔<br>• The ocean is becoming more acidic as increasing amounts of atmospheric carbon dioxide ($CO_2$) are absorbed at the sea surface. Models and measurements suggest about a 30% decrease in surface pH (an increase in acidity) and a 16% decrease in carbonate ion concentrations since 1750.<br>• **The rate of change in pH is faster than anything experienced in the last 55 million years and is causing concern for marine ecosystems and species.** | **Medium Confidence** ↔<br>• Oceans will continue to acidify with increasing $CO_2$ emissions.<br>• Whilst we have high confidence that ocean acidification will continue, subsequent impacts on ecosystems are less well understood.<br>• Future increases in ocean acidity may have major negative impacts on some shell and skeleton-forming organisms by 2100. |
| **Atlantic Heat Conveyor** *NOC; Cefas; MOHC; Reading University* | **Medium Confidence** ↑<br>• Daily observations of the Atlantic heat conveyor began in 2004, revealing substantial daily to seasonal variability. At present the record length is too short to determine inter-annual variability or longer-term trends.<br>• **Observations and ocean models provide some evidence for recent slowing at some latitudes, during the 1990s and early 2000s. However, we do not yet have compelling evidence for a direct influence of changes in the Atlantic heat conveyor on climate in and around the North Atlantic over recent decades.** | **Medium Confidence** ↑<br>• It is very likely that the Atlantic heat conveyor will slow this century, with models predicting an average 25% reduction of pre-industrial strength. |
| **Salinity** *Marine Scotland; Cefas; IMGL; NOC; PML; SAMS* | **Medium Confidence** ↔<br>• The shelf sea and oceanic 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 shelf sea waters of the Irish Sea, southern North Sea and western Scotland.<br>• **Salinity of the deep waters of the North Atlantic decreased between 1960–2000 but has been stable for the last decade.** | **Low Confidence** ↔<br>• **The salinity of shelf seas and oceanic surface waters may decrease slightly, though there are considerable uncertainties due to the influence of climate-driven changes in precipitation, evaporation, ocean circulation and ice-melt.** |

## Shelf Sea Stratification
*NOC; Cefas*

### WHAT IS ALREADY HAPPENING — Medium Confidence ↔

- There is some evidence that temperature stratification over the north-western European shelf seas is beginning slightly earlier in the year.
- **There is no suggestion of strengthening of stratification beyond the normal inter-annual variability.**

### WHAT COULD HAPPEN — Low Confidence ↔

- **Models project that by 2100 thermal stratification will begin around seven days earlier and end five to ten days later, decreasing the period of vertical shelf sea mixing.**
- The strength of stratification in north-western European Shelf Seas could increase in response to changes in seasonal heating and rainfall.
- **Changes to stratification of coastal waters caused by inputs of fresh water (from changes in rainfall) cannot yet be predicted by existing models.**

## Coastal Erosion
*University of Plymouth*

### WHAT IS ALREADY HAPPENING — High Confidence ↔

- Coastal erosion is a complex process that has a variety of causes, with rising sea level being only one of them. Whereas climate change and relative sea-level rise are global and regional phenomena, respectively, coastal erosion is a local process.
- Currently, around 17% of the UK coastline experiences erosion (30% of the coastline in England; 23% in Wales; 20% in Northern Ireland; 12% in Scotland).
- Where the coast is protected by engineering structures (46% of England's coastline; 28% Wales'; 20% Northern Ireland's and 7% of Scotland's is protected by artificial structures), steepening of the intertidal profile and a narrowing of the intertidal zone resulting from rising sea levels commonly occurs.

### WHAT COULD HAPPEN — 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.

## Air-sea Exchanges of $CO_2$
*PML; Cefas; UEA*

### WHAT IS ALREADY HAPPENING — Low Confidence NEW

- **The ocean removes about one quarter of atmospheric $CO_2$ emissions from human activity.**
- **Some areas of the ocean absorb more $CO_2$ than others; some areas release $CO_2$ back to the atmosphere.**
- **The north-west European shelf seas are thought to be an area of $CO_2$ uptake.**
- **The efficiency of $CO_2$ uptake by some areas of the ocean, including the north-east Atlantic, may be decreasing.**

### WHAT COULD HAPPEN — Low Confidence NEW

- **Increases in atmospheric $CO_2$ will drive an increase in the $CO_2$ content of the surface waters of the ocean. This is expected to increase the partial pressure of $CO_2$ to double its pre-industrial level by 2050.**
- **The proportion of $CO_2$ from anthropogenic emissions taken up by surface waters may decrease as sea surface temperature rises (reducing solubility) and $CO_2$ content increases (reducing buffering capacity). Other processes that affect $CO_2$ uptake are less well understood (e.g. stratification, upwelling, ocean circulation and primary production).**

## Air-sea Exchanges of Heat and Water
*NOC*

### WHAT IS ALREADY HAPPENING — Low Confidence ↔

- The exchanges of heat and water between the ocean and the atmosphere play an important role in driving variability in the circulations of both the atmosphere and the ocean.
- **An increase in ocean heat content has been identified, both globally and for the North Atlantic since 1960 (with an estimated upper limit of about 0.5 watts per square metre).**

### WHAT COULD HAPPEN — Low Confidence ↔

- **Obtaining reliable predictions of future changes in the air-sea heat and freshwater fluxes in the UK marine environment is difficult as the anthropogenic signal is small and may be strongly influenced by changes due to natural variability in the climate system.**

# Regional Snapshots of Marin

## What Is Already Happening

This map shows some of the changes in each regional sea. It is noticeable that it is in the south that many of the changes are being observed.

### Region 1 – Northern North Sea

- Squid are becoming more abundant off north-east Scotland creating new opportunities for fisheries.
- Since 2000 breeding success of seabirds such as Arctic skua, black-legged kittiwake, and shag has declined due to decreased food availability linked to climate change.

### Region 2 – Southern North Sea

- The warm water intertidal topshell, *Gibbula umbilicalis* is now established on rocky shores.
- The largest rate of warming in UK sea-surface temperature (1984–2008, ~0.7 °C/decade).
- The largest rate of warming in UK marine air temperature (1984–2008, 0.6 °C/decade).
- Some evidence that warmer conditions have been coincident with increased numbers of the warm-water bivalve *Abra alba*.
- Red seaweed *Caulacanthus ustulatus*, introduced from Asia, now present in Kent.

### Region 3 – Eastern English Channel

- Net erosion of saltmarshes in recent decades.
- Red seaweed *Caulacanthus ustulatus*, introduced from Asia, now present in Kent.
- The warm water red tuft alga, *Chonodracanthus aciculatris*, increased coverage in lower shores.

### Region 4 – Western English Channel, Celtic Sea and South-West Approaches

- Increased incidences of disease outbreaks in the pink sea fan *Eunicella verrucosa* linked to increased temperatures.
- Warm water kelp *Saccorhiza polyschides* showing massive increases in abundance and cold water *Alaria esculenta* decreasing in abundance.
- Red seaweed *Caulacanthus ustulatus*, introduced from Asia, now present in Devon and Cornwall.
- Large observed populations of warm-water copepod *Calanus helgolandicus*.
- Coldwater alga *Pelvetia canaliculata* declined in estuaries.
- New fisheries have developed for warm water species. Observed seabass stock biomass has quadrupled since 1985.
- The warm water red tuft alga, *Chonodracanthus aciculatris*, increased coverage in lower shores.
- Net erosion of saltmarshes in recent decades.

### Region 5 – Irish Sea and North Channel

- Northern limit of honeycomb worm *Sabellaria alveolata* extending.

### Region 6 – Minches and Western Scotland

- Relict populations of the cold-water copepod *Calanus finmarchicus* persist in some sea lochs but are vulnerable to changing conditions.

### Region 7 – Scottish Continental Shelf

- Since 2000 breeding success of seabirds such as Arctic skua, black-legged kittiwake, and shag has declined due to decreased food availability linked to climate change.

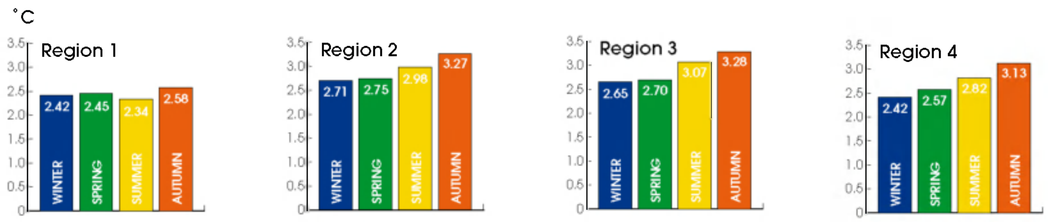
### Region 8 – Atlantic North-West Approaches, Rockall Trough and Faroe-Shetland Channel

- Since 1970 waters between 0–600m have warmed and waters between 0–800m have become more saline.

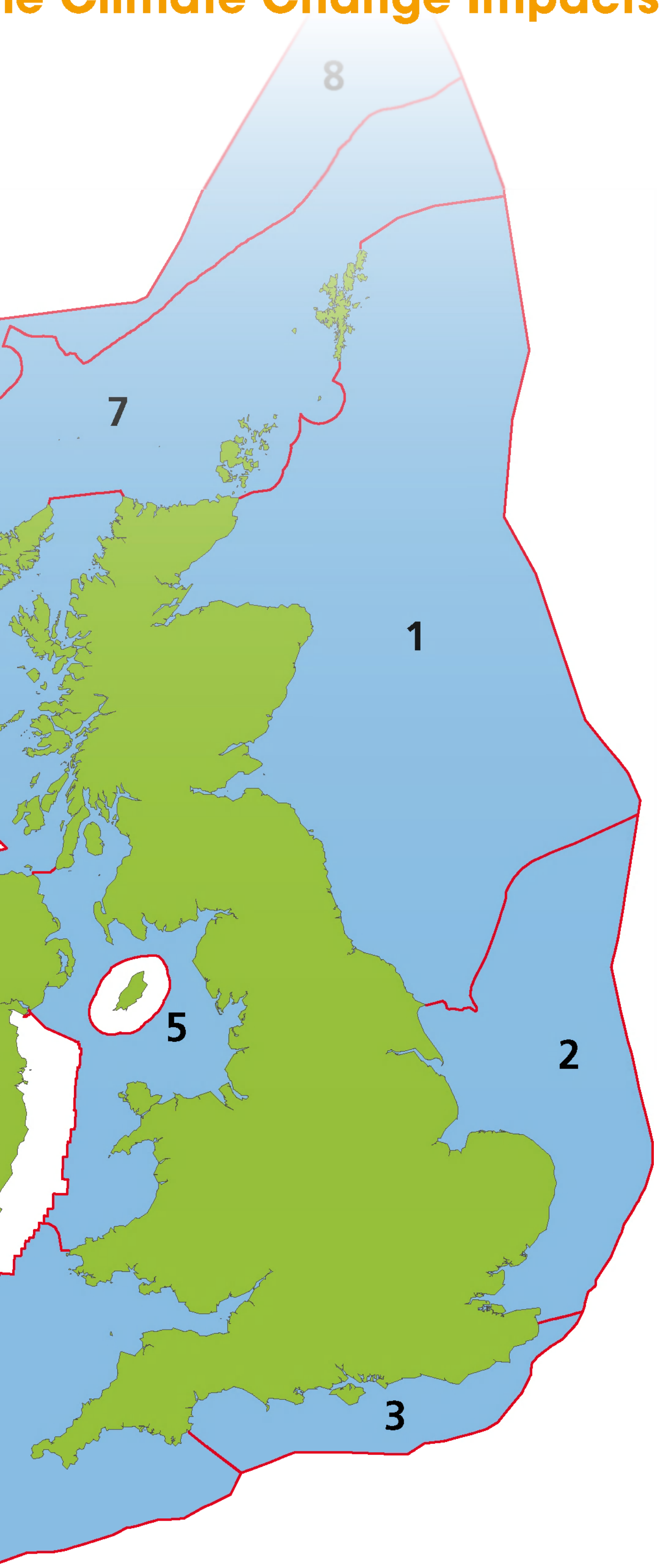

## Future Sea Surface Temperature

Seasonal mean sea surface temperature increases for the 2070–2099 period (compared with a 1960–1990 baseline). Changes are based on the UKCP09 model projections under a medium greenhouse gas emissions scenario.

*Data courtesy of Met Office Hadley Centre.*



# ne Climate Change Impacts




## What Could Happen

**Based on UKCP09 projections these are some possible consequences of climate change in each regional sea.**

### Region 1 – Northern North Sea

- 7–54cm sea-level rise projected in Edinburgh between 1990 and 2095 under a medium greenhouse gas emission scenario.

### Region 2 – Southern North Sea

- 21–68cm sea-level rise projected in London between 1990 and 2095 under a medium greenhouse gas emission scenario.
- Built structures will be impacted by projected changes in winter significant wave height more so than in most other regions.

### Region 3 – Eastern English Channel

- Sea-level rise and storm surge changes are likely to be most severe leading to further decreases in saltmarsh extent.

### Region 4 – Western English Channel, Celtic Sea and South-West Approaches

- Increased tendency for stratification could lead to offshore blooms including *Karenia mikimotoi* which has been associated with fish kills and benthic mortalities in coastal waters.
- 21–68cm sea-level rise projected in Cardiff between 1990 and 2095 under a medium greenhouse gas emission scenario.

### Region 5 – Irish Sea and North Channel

- Built structures will be impacted by projected changes in winter significant wave height more so than in most other regions.
- 7-55cm sea-level rise projected in Belfast between 1990 and 2095 under a medium greenhouse gas emission scenario.

### Region 6 – Minches and Western Scotland

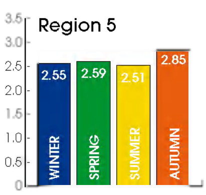
- Increased tendency for stratification could lead to offshore blooms including *Karenia mikimotoi* which has been associated with fish kills and benthic mortalities in coastal waters.

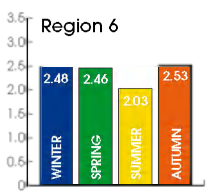
### Region 7 – Scottish Continental Shelf

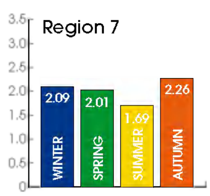
- Increased tendency for stratification could lead to offshore blooms including *Karenia mikimotoi* which has been associated with fish kills and benthic mortalities in coastal waters.

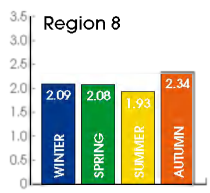
### Region 8 – Atlantic North-West Approaches, Rockall Trough and Faroe–Shetland Channel

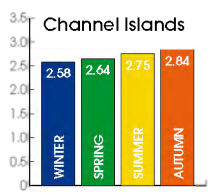
- Surface layers are likely to be stratified for a longer period during year by the end of the century.
- Increased tendency for stratification could lead to offshore blooms including *Karenia mikimotoi* which has been associated with fish kills and benthic mortalities in coastal waters.



# Climate Change: impacts on our vision for a **healthy and biologically diverse** marine ecosystem

To access the full peer reviewed reports, go to: **www.mccip.org.uk/arc/healthy**

As the marine ecosystem is highly interconnected through predator-prey relations, the direct impacts of ocean climate change have 'knock-on' effects up the food-chain. For example, recent warmer conditions and associated changes 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.

Where headline messages under each topic are new for 2010-2011, they are highlighted in bold text. Arrows show change in confidence since the 2007-2008 MCCIP Annual Report Card. Where a topic is referred to in the 'regional snapshot' map, a map symbol appears.

## Plankton
*SAHFOS; Strathclyde University*

### WHAT IS ALREADY HAPPENING — High Confidence ↑

- 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.
- There has been a northward shift in the distribution of many plankton species by more than 10° latitude over the past 50 years.
- The seasonal timing of plankton production has altered with some species appearing up to four to six weeks earlier than 20 years ago, which is having an effect on predators.
- **The effects of an abrupt ecosystem shift in the late 1990s were most pronounced in regions of the north-eastern Atlantic near the 9-10°C sea surface temperature isotherm, a critical thermal boundary between 'warm' and 'cold' water ecosystems. As waters warm this boundary has moved northwards.**

### WHAT COULD HAPPEN — Low Confidence ↔

- Future warming is likely to alter the geographical distribution of phytoplankton and zooplankton, affecting ecosystem services such as oxygen production, carbon sequestration and biogeochemical cycling.

## Fish
*Cefas; Strathclyde University*

### WHAT IS ALREADY HAPPENING — Medium Confidence ↔

- **Some fish distributions have moved northwards over the past 30 years by between 50 to 400km, with coldwater species such as monkfish and snake blenny moving the furthest. At the same time, some have moved into deeper waters at an average rate of about 3.5 metres per decade.**
- **Warmer temperatures around the UK are correlated with poor conditions for survival of cod larvae and cod growth, but enhanced growth rates in sole (a warm-water species).**
- **Diadromous species (which spend some of their life in both fresh and marine waters) such as salmon and eel have been shown to be particularly vulnerable to climate change (water temperature and river flow) with impacts on both the freshwater and marine phases.**

### WHAT COULD HAPPEN — Medium Confidence ↑

- **By 2050, climate change may lead to pelagic species (such as herring and anchovy) moving northward by an average of 600km and demersal species (such as cod and haddock) by 220km.**
- **Changes to currents may have an impact on the dispersal of fish eggs and larvae. It is anticipated that winter and early spring spawners (such as cod and plaice) will experience poor larval survival, whereas warmer-water species (such as sprat) may benefit.**

## Seabirds
*JNCC; CEH*

### WHAT IS ALREADY HAPPENING — Medium Confidence ↔

- **Between 2000 and 2008, the total number of seabirds breeding in the UK decreased by approximately 9%. Breeding success also declined. Climate change is partly responsible.**
- **Major changes in plankton abundance in the North Sea have contributed to the reduction in quality and abundance of prey species such as sandeels.**
- **The greatest reductions in breeding success of species most sensitive to food shortages, such as Arctic skua, black-legged kittiwake and shag are seen in the Northern North Sea and Scottish Continental Shelf.**

### WHAT COULD HAPPEN — Low Confidence ↔

- **Models predict that by 2100, UK climate will no longer be suitable for great skua and Arctic skua. The same models predict that the geographic range of black guillemot, common gull and Arctic tern will shrink so that only Shetland and the most northerly tips of mainland Scotland will hold breeding colonies.**
- Any increased storminess would reduce the amount of safe breeding habitat for shoreline-nesting species (e.g. terns) and create unfavourable foraging conditions at sea, which may lead to starvation of adults and chicks of some species.

## Marine Mammals
*SWF; SMRU; University of Aberdeen*

### WHAT IS ALREADY HAPPENING — Low Confidence ↔

- Evidence of impacts from climate change are difficult to distinguish from the impacts of human activities such as those that cause prey depletion, incidental capture in fishing gear, pollution and disturbance.
- **In the temperate zone, some species of toothed whales and dolphins are showing shifts in distribution, which may be linked to increasing sea temperatures.**

### WHAT COULD HAPPEN — Low Confidence ↔

- **The most likely impacts will be from changes in prey distribution and abundance.**
- **Species that have relatively narrow habitat requirements are the most likely to be affected (e.g. shelf sea species like harbour porpoise, white-beaked dolphin and minke whale).**
- **Reduced plankton availability may directly affect some baleen whale species that feed at least in part upon zooplankton.**
- **Increased coastal flood risk could affect seal haul-out and breeding sites in low-lying areas and caves.**

| | WHAT IS ALREADY HAPPENING | WHAT COULD HAPPEN |
|---|---|---|
| **Waterbirds**<br>*BTO* | **Low Confidence** NEW<br>• Overwintering wader distributions have shown an eastward and northward shift. In recent years numbers of some species have declined as birds have overwintered further east in Europe as conditions have improved there.<br>• Overwintering wildfowl are showing similar distribution shifts. | **Low Confidence** NEW<br>• Waders and wildfowl may be more susceptible to intermittent severe weather events in the future.<br>• Changes in the Arctic and sub-Arctic are expected to lead to reduced availability of suitable breeding grounds and increased predation pressure. |
| **Non-natives**<br>*Queen's University, Belfast; Marine Scotland; MBA* | **Medium Confidence**<br>• The distribution and reproductive capabilities of many non-native marine species have been limited by water temperatures.<br>• The introduced Pacific oyster (*Crassostrea gigas*) spread from oyster farms in the early 1990s, becoming established in southern England. Similarly new self-sustaining populations are now established in Northern Ireland with recruitment occurring in favourable years.<br>• Rising water temperatures may have contributed to the expansion in range of a number of species such as the bryozoan *Bugula neritina*, previously restricted to warm water areas such as power station outlets, and the red seaweed *Caulacanthus ustulatus* which was introduced from Asia and spread rapidly to Devon in 2004, Cornwall in 2005 and Kent in 2009. | **Low Confidence**<br>• Changes in ocean physics and chemistry could favour some non-native species over native species.<br>• Current sea temperature projections are thought likely to result in certain species such as *Crassostrea gigas* recruiting every year in Northern Ireland, Wales and south-west England by 2040. |
| **Coastal Habitats**<br>*NE; CCW; National Coastal Consultants; SNH* | **Medium Confidence**<br>• Coastal habitats are being affected by changes to the amount of sediment being supplied and removed as a result of natural processes and human intervention.<br>• Past human intervention and modification of coastal habitats means they have a reduced capacity to adapt naturally to climate change impacts. | **Low Confidence**<br>• Continued sea-level rise, and other climate change related factors are expected to have an impact on the extent, distribution and quality of various coastal habitats. |
| **Intertidal Habitats**<br>*MBA* | **Medium Confidence**<br>• Biodiversity is increasing in southern areas as warm water species extend their distributions faster than cold water species are retreating.<br>• Changes in geographic distributions of rocky shore species have continued with the range limits of southern species moving up to 12km further north (e.g. *Osilinus* species) between surveys undertaken in July 2007 and July 2009.<br>• Population abundances of the topshell *Gibbula umbilicalis* have increased throughout the UK and in warmer southern areas they have switched to having two periods of gonad maturation per year. This was observed for the first time in 2008/2009. Such a strategy is more characteristic of populations inhabiting warm waters and lower latitudes. | **Medium Confidence**<br>• The further development of hard coastal defences to tackle sea-level rise could provide 'stepping stones', enabling some rocky shore species to further expand their range.<br>• More information is required to quantify the impacts of climate change on seagrass beds, mudflats, and other soft sediment communities. |
| **Shallow and Shelf Subtidal Habitats**<br>*Cefas; Oxford University; MBA; University of Wales, Bangor* | **Low Confidence**<br>• We lack information on ecosystem dynamics over the range of shallow and shelf subtidal habitats, which hinders our ability to identify and understand large-scale climate change effects.<br>• There is no obvious signal of warming effects in sediments in southern and south-western areas where changes would be most expected. However, changes in crustacean abundance in some locations and the occurrence of previously undocumented species in others (e.g. brittle star *Amphiura incana* and shrimp *Athanas nitescens*) suggest some degree of climate-influence.<br>• Increased seawater temperatures have been linked with disease outbreaks in seafans, changes in algae distribution and abundance, and the appearance and increased occurrence of a previously unrecorded warm-water barnacle *Solidobalanus fallax* in southern and south-western areas. | **Low Confidence**<br>• Changes already documented in soft-sediment communities are expected to continue, and probably escalate, in response to the cumulative effects of seawater warming and ocean acidification.<br>• Cold-water coral species and maerl may experience shifts in distribution as a result of intolerance to raised seawater temperature and altered chemistry, with knock-on effects on community composition and function. |
| **Deep-Sea Habitats**<br>*SAMS; NOC* | **Low Confidence** NEW<br>• A detailed assessment of climate change impacts on deep-sea ecosystems is difficult due to the scarcity of sustained observations. Climate driven changes in surface waters could already be having a direct impact through the quantity of food being delivered to the sea bed in any given year. | **Low Confidence** NEW<br>• Predicting future changes is extremely difficult due to lack of baseline data and appropriate models at this time. |

# 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).

To access the full peer reviewed reports, go to: **www.mccip.org.uk/arc/clean**

Where headline messages under each topic are new for 2010-2011, they are highlighted in bold text. Arrows show change in confidence since the 2007-2008 MCCIP Annual Report Card. Where a topic is referred to in the 'regional snapshot' map, a map symbol appears.

## Coastal Flooding

*NOC; Dundee University; EA; Marine Institute, Ireland*

### WHAT IS ALREADY HAPPENING — High Confidence ↑

- **Over the past century, natural variations in storm frequency and magnitude over 10-20 year cycles have been the most important climatic factor driving coastal flood risk. However, changes in land use and movement of people and key services to coastal areas over this time period has generally increased vulnerability to coastal flooding.**

### WHAT COULD HAPPEN — Low Confidence ↔

- **Coastal flood events in the future are far more likely to be exacerbated by rising sea levels than by changes to waves or storm surges.**
- **It has been estimated that a 40cm sea-level rise, which is broadly in line with UKCP09 projections by 2100 under a medium emissions scenario, would increase the number of properties at risk in eastern England from around 270,000 to 400,000.**

## Nutrient Enrichment

*Strathclyde University*

### WHAT IS ALREADY HAPPENING — Low Confidence ↔

- Changes have occurred in nutrient concentrations in UK waters but it is not possible, at present, to distinguish between the relative contributions of climate, and other natural and anthropogenic factors, in driving these changes.

### WHAT COULD HAPPEN — Low Confidence ↔

- Modelling studies suggest nutrient concentrations in the sea may decline if summers become drier. Large uncertainty remains in such predictions given the difficulties in confidently predicting the driving conditions (e.g. rainfall; changes to local ocean currents) and what may happen to anthropogenic inputs.

## Harmful Algal Blooms (HABs)

*Marine Scotland; Cefas; AFBINI; Marine Institute, Ireland; NUI, Galway; SAHFOS; SAMS*

### WHAT IS ALREADY HAPPENING — Medium Confidence ↔

- The distribution of selected HAB species in the north-east Atlantic has changed over the last four decades.
- **In Scottish waters the incidence of PSP (paralytic shellfish poisoning) toxicity of blue mussels (*Mytilus edulis*), primarily associated with the dinoflagellate genus *Alexandrium*, appears to have decreased since the turn of the century.**

### WHAT COULD HAPPEN — Low Confidence ↓

- **An increase in tendency for stratification of the water column could influence the development of selected offshore blooms, some of which e.g. *Karenia mikimotoi*, have been associated with fish kills and benthic mortalities in coastal waters in south-western England, western Scotland, Orkney and Shetland.**
- **Climate change may influence the toxicity of some HAB populations as a result of any changes to species diversity, nutrient availability, temperature and irradiance (cloud cover).**
- **Increases in sea temperature could increase the geographic range of species that are not currently observed in UK waters. One candidate is *Gymnodinium catenatum*, a dinoflagellate associated with PSP events.**

## Pollution

*Cefas; EA; Leeds University; Marine Scotland; University of Wales, Aberystwyth*

### WHAT IS ALREADY HAPPENING — Medium Confidence ↑

- The current state of knowledge specifically on the impacts of climate change on marine pollution is limited and the knowledge gaps are numerous and extensive.

### WHAT COULD HAPPEN — Medium Confidence ↑

- **Drought conditions will result in reduced dilution of chemicals whilst any increase in high rainfall events over land would increase runoff via sewers.**
- **Any increase in the frequency of storm events and storm intensity would impact on pollution loading through increased volumes of sewage overflow discharges and riverine microbial fluxes, making compliance with the aims of the Shellfish Waters Directive and the Bathing Water Directive difficult.**

## Human Health Impacts (marine vibrios)

*Cefas*

### WHAT IS ALREADY HAPPENING — Low Confidence NEW

- **Marine vibrios are an important group of pathogens with human health implications, linked to increasing seawater temperature and reduced salinity. They can cause seafood associated gastro-enteric or septicaemia illness that may occasionally be fatal.**
- **Infections are uncommon in the UK, and almost always related to overseas travel. However, reports of disease caused by marine vibrios have increased in some parts of Europe over recent years, and have tended to follow periods of unusually warm weather.**

### WHAT COULD HAPPEN — Low Confidence NEW

- **Marine vibrio infections are predicted to occur as sea surface temperatures around the UK rise, possibly exacerbated by declining salinity as a result of localised intense rainfall events. The impacts maybe further increased by expansion in ranges of zooplankton that are important vectors for these species.**

# Climate change: impacts on our vision for **commercially productive** seas

The impacts of climate change on the commercial services provided by our seas are expected to be significant. Sea-level rise, coastal flooding and storms and waves could affect ports, shipping and built structures. Fishing and fish farming will be impacted by temperature change and plankton availability. Rising temperatures should have some positive impacts on coastal tourism and marine recreation, whilst retreating Arctic sea ice may open up new (seasonal) shipping routes.

To access the full peer reviewed reports, go to: **www.mccip.org.uk/arc/productive**

Where headline messages under each topic are new for 2010-2011, they are highlighted in bold text. Arrows show change in confidence since the 2007-2008 MCCIP Annual Report Card. Where a topic is referred to in the 'regional snapshot' map, a map symbol appears.

## Shipping
*DfT; University of Plymouth*

**WHAT IS ALREADY HAPPENING** — Low Confidence ↔

- **Retreating Arctic sea ice is increasing the accessibility of the 'Northern Sea Route' between Europe and Asia for a limited period of the year. In September 2009, two cargo ships symbolically utilised the 'Northern Sea Route'.**

**WHAT COULD HAPPEN** — Low Confidence ↔

- **Sea-level rise of the magnitude projected by UKCP09 will increase the vulnerability of port operations to flooding.**
- Future changes to wind speed and storminess could lead to reduced loads, route changes and restrictions for some ships.

## Tourism
*Oxford University*

**WHAT IS ALREADY HAPPENING** — Medium Confidence ↓

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

**WHAT COULD HAPPEN** — Medium Confidence ↑

- **Warmer summers are expected to lead to an extended tourist season in the UK, especially at the coast, leading to increased revenues, new infrastructure, increased employment and enhanced watersport opportunities.**
- **Increased visitor numbers could overwhelm small coastal communities with implications for energy, water and waste management and environmental degradation.**
- **Any increase in coastal flooding, erosion and extreme events would be expected to increase damage to coastal communities, tourist accommodation and transport links, whilst also posing an increased safety risk to marine recreation activities.**

## Built Structures
*ABPMer; Cefas*

**WHAT IS ALREADY HAPPENING** — Low Confidence ↔

- **100-year analyses of both mean and significant wave heights are typically used to inform design criteria for offshore built structures such as oil installations. These studies reveal a high degree of natural variability in wave climate, which makes interpreting the impacts of climate change on offshore built structures very difficult.**
- **There is limited published evidence that climate change has led to changes in operational practices of offshore installations.**
- Sea-level rise has affected the planning of coastal structures.

**WHAT COULD HAPPEN** — Low Confidence ↔

- Continued sea-level rise, changes to significant wave heights and any change to storminess could have an adverse impact on built structures.
- Any change in currents will affect structure erosion and patterns of scour both in coastal and offshore areas.
- **Based on the UKCP09 projections only, built structures located in the southern North Sea and the Irish Sea and North Channel regions will be impacted the most by changes in winter significant wave height.**

## Fisheries
*Cefas; Strathclyde University; UEA*

**WHAT IS ALREADY HAPPENING** — Medium Confidence ↔

- **There is evidence that locations where high catches of cod, haddock, plaice and sole occur, have moved over the past 80-90 years. Climate change may be a factor but fishing and habitat modification have also had an important effect.**
- **Shifting distributions of fish, partly as a result of climate change are having an impact on the effectiveness of some fishery closure areas and on apportionment of fishery resources between neighbouring countries (e.g. mackerel in the north-east Atlantic).**
- **New fisheries have developed for a number of warmer-water species including seabass, red mullet, anchovy and squid. The stock biomass of adult seabass in the Western Channel has quadrupled since 1985 from 500t, to over 2000t in 2004/2005.**

**WHAT COULD HAPPEN** — Low Confidence ↔

- **The UK is expected to benefit from slightly (i.e. + 1–2% compared to present) higher fishery yields by 2050, although the Irish Sea and English Channel may see a reduction.**
- **Models suggest that cod stocks in the Celtic and Irish Seas might disappear completely by 2100, while those in the North Sea are expected to decline. Climate change has been reducing the maximum sustainable yield of cod in the North Sea by around 32,000t per decade.**
- **Very little work has been carried out on the social and economic implications of climate change for the UK fishing industry. Calculations suggest, however, that consequences will be significant for fishery-dependent communities in the north of Scotland and south-west England.**
- **Ocean acidification may pose a significant threat to the UK shellfish industry, but more research is required.**

## Aquaculture
*Marine Scotland; AFBINI; University of Maine*

**WHAT IS ALREADY HAPPENING** — 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 (47% in England and Wales; 33% in Northern Ireland; 20% in Scotland for 2008).

**WHAT COULD HAPPEN** — Low Confidence ↔

- Rising water temperatures could increase growth rates for some fish species (e.g. Atlantic salmon), but may also cause thermal stress for cold-water fish species (e.g. cod and Atlantic halibut) and intertidal shellfish.
- New species (e.g. sea bass, bream) may be able to be cultivated.
- Farmed species may become more susceptible to a wider variety of diseases as temperatures increase. Any increase in harmful algal and jellyfish blooms may lead to additional fish kills and closure of some shellfish harvesting areas.

# ARC Online and more information ...

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

## What is MCCIP?

The Marine Climate Change Impacts Partnership (MCCIP) is a partnership between scientists, government, its agencies, non-governmental organisations (NGOs) and industry. The principal aim is to provide a coordinating framework for the UK, so as to be able to transfer high quality evidence on marine climate change impacts, and guidance on adaptation and related advice, to policy advisers and decision-makers.

Partners are: Agri-Food and Biosciences Institute, Northern Ireland; Centre for Environment, Fisheries and Aquaculture Science; Countryside Council for Wales; Department of Energy and Climate Change; Department for Environment, Food and Rural Affairs; Department of the Environment, Northern Ireland; EDF; Environment Agency; Joint Nature Conservation Committee; Marine Scotland Science; Marine Environmental Change Network; Marine Institute, Ireland; Natural England; Natural Environment Research Council; Royal Society for the Protection of Birds; Scottish Environment Protection Agency; Scottish Government; Scottish Natural Heritage; Sir Alister Hardy Foundation for Ocean Science; States of Guernsey; States of Jersey; The Crown Estate; UK Climate Impacts Programme; UK Met Office; Welsh Assembly Government.

## Quality Assured Science

The MCCIP Annual Report Card working group commissioned around 100 of the leading UK marine climate scientists from almost 40 different institutes to contribute to the 30 topics covered in this report card. Over 30 specialist experts peer-reviewed the full topic submissions, which provide the detailed supporting information behind this summary card.

## List of Contributors

**ABPMer** S. Hunt
**AFBINI** R. Gowan; M. Service
**Bristol University** A. Ridgwell; D. Schmidt
**British Trust for Ornithology (BTO)** G. Austin
**Countryside Council for Wales (CCW)** P. Rhind
**Cefas** C. Baker-Austin; S. Birchenough; J. Bremner; S. Dye; L. Fernand; J. van der Kooij; S. Kroeger; S. Milligan; J. Pinnegar; R. Rangdale; J. Rees; D. Sheahan
**Centre for Ecology and Hydrology (CEH)** F. Daunt
**Department for Transport (DfT)** R. Watson
**Dundee University** T. Ball
**Environment Agency** B. Donovan; J. Maud; A. Wither
**Environmental Research Institute, Thurso (ERI)** D. Woolf
**Isle of Man Government Laboratory (IMGL)** T. Shammon
**Joint Nature Conservation Committee (JNCC)** I. Mitchell
**Leeds University** A. McDonald
**Marine Biological Association (MBA)** J. Bishop; C. Brownlee; N. Mieszkowska; D. C. Schroeder
**Marine Institute, Ireland** J. Silke; G. Westbrook
**Marine Scotland** E Bresnan; M. Gubbins; S. Hughes; T. McCollin; C. Moffat
**Met Office Hadley Centre (MOHC)** J. Kennedy; J. Lowe; J. Tinker; R. Wood
**National Coastal Consultants** J. P. Doody
**National Oceanography Centre (NOC)** D. Berry; S. Cunningham; N. P. Holliday; J. Holt; K. Horsburgh; J. A. Hughes; S. Josey; E. Kent; R. Marsh; J. Read; J. Sharples; C. Wallace; J. Wolf
**Natural England (NE)** S. Rees
**National University of Ireland (NUI), Galway** R. Raine
**Oxford University** P. Henderson; M. Simpson
**Plymouth Marine Laboratory (PML)** H. S. Findlay; N. Hardman-Mountford; E. Litt; S. Mangi; T. Smyth; C. Turley
**Queen's University, Belfast (QUB)** C. Maggs; F. Mineur
**Reading University** T. Kuhlbrodt
**Scottish Association for Marine Science (SAMS)** K. Davidson; D. Hughes; M. Inall; T. Sherwin
**Scottish Environment Protection Agency (SEPA)** J. Dobson
**Scottish Natural Heritage (SNH)** S. Angus
**Sea Mammal Research Unit (SMRU)** I. Boyd
**Sea Watch Foundation (SWF)** P. Evans
**Sir Alister Hardy Foundation for Ocean Science (SAHFOS)** M. Edwards; A. McQuatters-Gollop
**Strathclyde University** M. Heath
**UK Climate Impacts Programme (UKCIP)**
**University of Aberdeen** C. MacLeod
**University of East Anglia** D. Bakker; W. Cheung; U. Schuster; A. Watson
**University of Maine** I. Bricknell
**University of Plymouth** G. Masselink; P. Russell; P. Wright
**University of Wales, Aberystwyth** D. Kay; C. Stapleton; M. Wyer
**University of Wales, Bangor** H. Hinz; S. Jenkins

MCCIP Marine Climate Change Impacts Partnership

**www.mccip.org.uk/arc**

## Annual Report Card working group

The delivery of the MCCIP Annual Report Card is overseen by the MCCIP Annual Report Card working group. In addition to the report card editors, the members of this group are: M Cox (Scottish Government); S Dye (Cefas); M Frost (MBA); D Laffoley (Natural England); J Lartice (Defra) and E Verling (JNCC).

## What's next for MCCIP?

Whilst significant progress has been made in building the evidence base during the first five year programme of MCCIP, much work remains to be done to translate scientific evidence into action for the marine user community.

In late 2010, MCCIP's second five-year work programme is due to get underway. As part of an expanded programme, MCCIP will look to build on the evidence base to begin to collaboratively consider the next important stage of developing adaptation tools for the UK.

Innovative new 'climate smart' approaches to understanding and responding to marine climate risks are being developed, working closely with key sectors to build on current good practice and advise on appropriate adaptation tools and strategies.

Building and reporting on the evidence base will still be a key part of MCCIP's remit in phase II and 'impacts' reporting through the MCCIP Annual Report Card will continue to be a key output.

## 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

For further details about the work of MCCIP go to **www.mccip.org.uk**. If you have any further enquiries please contact us at **office@mccip.org.uk**.

Please cite this document as: MCCIP (2010). Marine Climate Change Impacts Annual Report Card 2010–2011. (Eds Baxter JM, Buckley PJ, and Wallace, CJ) Summary Report, MCCIP, Lowestoft, 12pp.