Climate change

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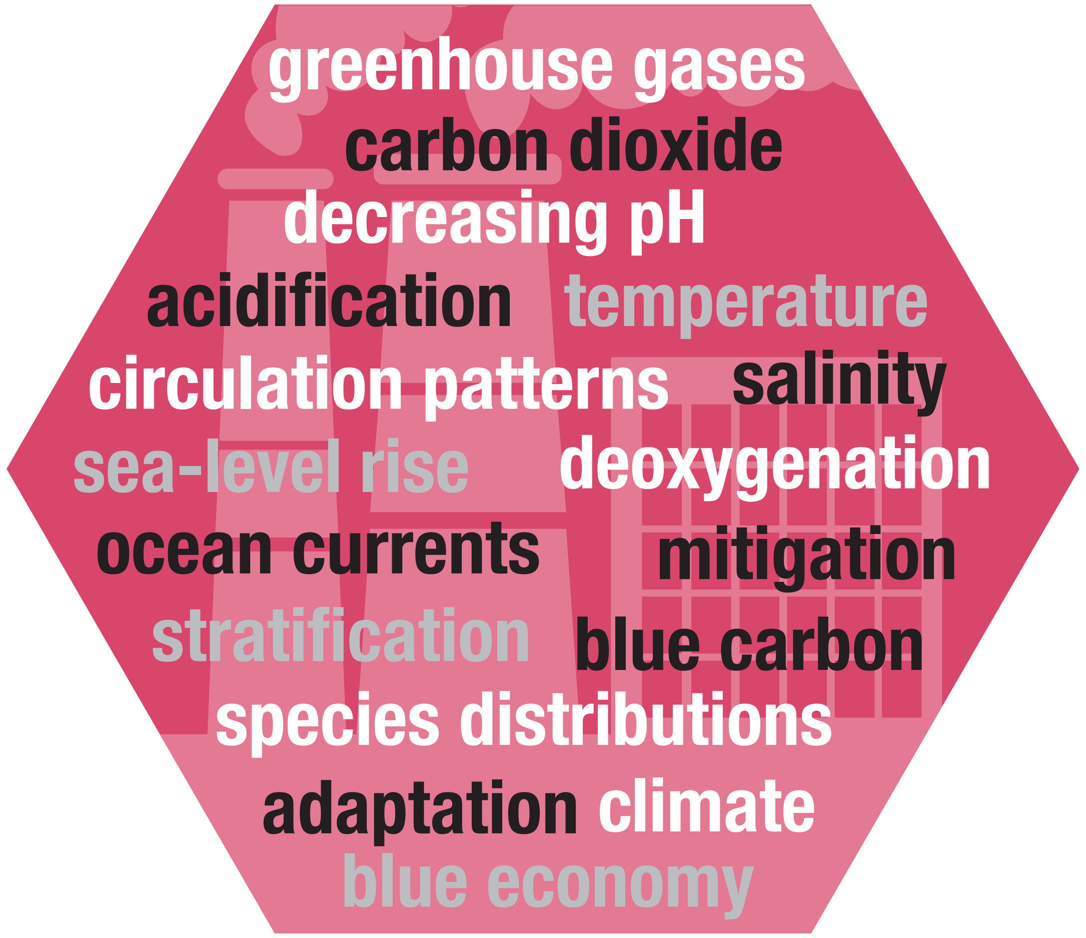
Assessments

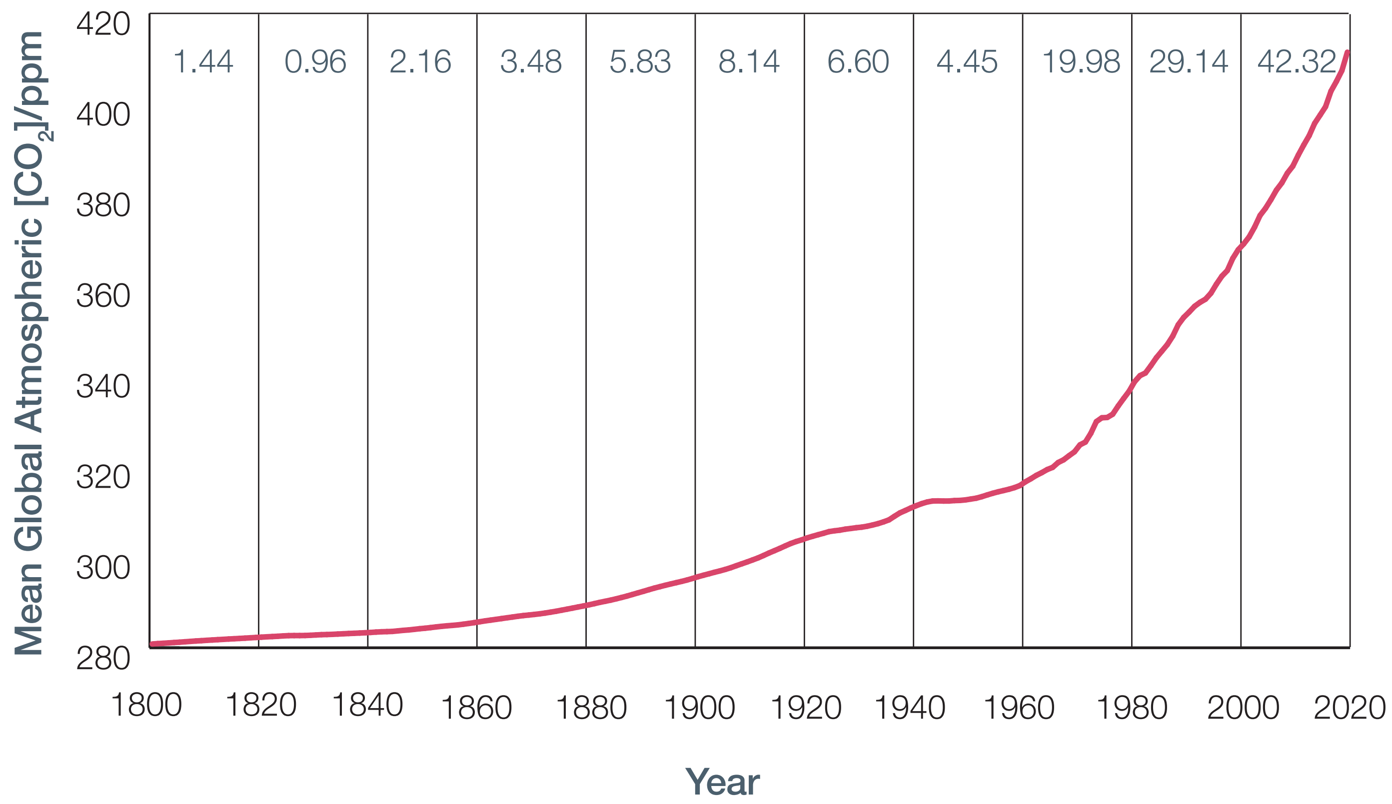
More information on the regions used in the Climate change assessment is available on the Assessment processes and methods page of the SMA2020 portal: **http://marine.gov.scot/sma/assessment-theme/assessment-processes-and-methods**

Key words



What is covered

Emissions of greenhouse gases, including carbon dioxide (CO_2) and methane (CH_4) continue to increase. The consequence of this is that changes in the ocean are occurring. The ocean has absorbed about 89% of the excess heat in the Earth's climate system resulting from the human activities that produce greenhouse gases, and between 20-30% of the additional carbon dioxide since the mid-1980s. This has led to an increase in water temperature, a reduction in dissolved oxygen and a decrease in pH globally. Sea-level rise, due to both the thermal expansion of water and the input of fresh water from the melting of glaciers and the ice sheets, will have an impact on coastal communities and infrastructure. These changes also have an impact on marine species and habitats. Adaptation to climate change and a reduction of greenhouse gas emissions can be supported by the use of the marine environment, for example through offshore wind and renewable energy. However, some future changes are already locked in due to the residence time of these greenhouse gases in the atmosphere.



Mean global atmospheric carbon dioxide concentration (ppm dry air) over the period 1800–2019 inclusive. The numbers along the top (units: ppm) are the difference over the 20 year period indicated by the vertical lines. ([Dataset downloaded from the Institute for Atmospheric and Climate Science, Zurich, Switzerland 27 Oct 2020](#)) other than the 2019 point which is the annual average at Mauna Loa, Hawaii which was used as the global mean was not available).

The basis of the assessment

This climate assessment uses the recent (last 10 years, but particularly the last 3 years) scientific literature, including several key reports and documents which have been published by the scientific community in the last two years. These are:

- **The IPCC Special Report on Global Warming of 1.5°C (SR1.5)** https://www.ipcc.ch/sr15/
- **The IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC)** https://www.ipcc.ch/srocc/home/
- **The Marine Climate Change Impacts Report Card 2020 and backing papers produced by the UK Marine Climate Change Impacts Partnership (MCCIP)** http://www.mccip.org.uk/impacts-report-cards/full-report-cards/2020/
- **The Scottish Ocean Climate Status Report 2016 prepared by Marine Scotland Science** https://data.marine.gov.scot/dataset/scottish-ocean-climate-status-report-2016

Summary of key messages

Effects on Scotland's seas of the increase in concentrations of atmospheric greenhouse gases (GHGs) are being observed. The rate and magnitude of these changes are geographically variable. While the atmospheric concentrations of GHGs continue to rise, additional and greater effects will be observed. However, the longer-term future will depend on the rate and direction of change in the concentration of atmospheric GHGs.

The key messages are summarised on the basis of:

- Physical changes.
- Coastal consequences.
- Fish and fisheries.
- Species and habitats.
- Impacts on the Blue Economy.
- Supporting the transition to net zero.

> “The impacts of climate change have already been observed in Scotland's seas with evidence of warming seas and increasing sea levels, for example. These changes are increasingly having an impact on the marine ecosystem.”
>
> Bee Berx, Topic lead

Physical changes

Scottish waters (coastal and oceanic) have warmed by between 0.05 and 0.07 °C per decade, calculated across the period 1870 to 2016. However, the warming trend in the last 30 years (1988 to 2017) is about 0.2 °C per decade, while northwards from the region of the Faroe-Shetland Channel trends are reaching 0.4 °C per decade.

Mean sea level around the coast of Scotland is increasing in all Marine Regions, with the largest changes in the last 30 years observed at Stornoway (Outer Hebrides SMR), Kinlochbervie (West Highlands SMR) and Lerwick (Shetland Isles SMR).

There has been a decline in the oxygen concentration in the water since 1990 in the stratified regions of the North Sea due to both a decrease in solubility resulting from warming and due to an increase in oxygen utilisation from changes in metabolic rates and community structure. Oxygen depletion and ocean warming together will, in the future, result in changes in the viable habitat for a number of species, including commercially important ones such as marine fish.

At Stonehaven, the seasonal range in pH can be as high as 0.3 pH units, however, currently there is not a dataset for Scottish waters that allows any trend in acidification to be detected.

In the last 20 years there has been a period of sustained high salinity in the offshore water masses. In areas with significant river inputs (Clyde, Forth, Inverness, Beauly, Cromarty and Dornoch Firths), stratification due to river run-off (input of fresh water) can occur year-round. There is currently no evidence that the strength of stratification in these regions is systematically changing.

Currently, there is no evidence that the ocean currents in Scottish waters are significantly changing due to climate change. However, the Atlantic Meridional Overturning Circulation (AMOC) will very likely slow down by the end of the century which will result in less heat conveyed northwards in the atmosphere and ocean around Scotland.

Coastal consequences

National assessments predict that coastal erosion and coastal flooding will be more significant issues in the future due to sea-level rise and wave-climate changes. Coastal habitats are also experiencing the effects of increased temperatures. The effects of these will be particularly profound for the exposed, low-lying dune-wetland habitat complexes such as those found in the Outer Hebrides.

Any shoreline management planning and coastal adaptation strategies will have to take account of transformative change to some semi-natural shorelines, significant maintenance challenges for existing built defences, and a longer-term need to consider relocating certain assets that are at risk.

Fish and fisheries

Communities of bottom-living fishes have shifted towards a dominance by warm-water species (e.g. lesser-spotted dogfish, hake, horse mackerel) and away from cold-water ones (e.g. Atlantic cod, Atlantic herring, sprat) as the sea water has warmed.

The biggest declines in occurrence of species in trawl surveys in waters off North-east Scotland have been in cold-water Atlantic cod and Atlantic herring.

Distributional shifts in species have been mainly linked to temperature changes but may also be partly due to changes in prey distribution.

Species richness on the west coast of Scotland has increased due to a rise in temperature.

Evidence from different fish species suggests climate change is having an impact on the timing of spawning, hatching and migration. For example, in Scottish waters the earlier development of Atlantic cod reproductive organs (gonads) and the delay of those in sandeel have been observed.

A temperature-related reduction in adult maximum body size in six commercial fish species (haddock, whiting, herring, Norway pout, plaice and sole) has been detected in the North Sea. This is due to temperature-related changes in oxygen demand and the metabolic cost of activities such as movement, reproduction and eating.

Whiting could increase in abundance as a result of rising temperatures and declines in predators such as Atlantic cod, but may also be compromised by changes in plankton and by ocean acidification.

Species and habitats

Oxygen depletion and ocean warming together will in the future result in changes in the viable habitat for a number of species.

Non-native species are appearing on Scotland's coasts, with many of these being warm-water species.

Models predict large-scale spatial declines in distribution of maerl beds under all IPCC Representative Concentration Pathways, ranging from 38% decline under the "low emission scenario" up to 84% decline under the "high emission scenario", with the most rapid rate of decline occurring up to 2050.

The apparent range shifts observed for some cetaceans around Scotland may reflect changing distributions of particular fish prey species in response to climate change.

Sea-level rise may affect current seal haul-out sites around Scotland, with some critical habitat, such as the Monach Isles (home to the largest grey seal colony in the eastern Atlantic) disappearing under water in future. However, it is unlikely this will happen at a rate that would prevent an adaptive shift in distribution to new haul-out sites.

There have been significant changes in plankton life forms in the last 30 years within the entire North Sea and North Atlantic Ocean. Climate change is one of multiple factors influencing long-term trends in plankton abundance in Scottish waters.

The possible long-term consequences of climate change on seabirds are not yet fully understood.

Impacts on the Blue Economy

Currently, no clear impacts due to climate change have been established for aquaculture of finfish or shellfish. This industry will face a number of challenges in the future likely to include an increased occurrence of pathogens and parasites, while the shellfish sector will likely experience impacts from ocean acidification.

Marine transport and coastal infrastructure, important parts of Scotland's coastal economy, are likely to experience the impacts of changes to extreme weather events (such as storms) and sea-level rise.

Supporting the transition to net zero

Marine renewable energy developments (including offshore wind and tidal in the future) will help to reduce greenhouse gas emissions.

Carbon Capture Utilisation and Storage (CCUS) will be needed to ensure the net zero legislation targets are met by 2045. The theoretical carbon dioxide storage capacity of the continental shelf adjacent to Scotland is 46 Gigatonnes.

Sedimentary carbon stores across the continental shelf are significant, with the Scottish sea lochs in particular providing hotspots of carbon burial. Other habitats with significant carbon stores are maerl beds, saltmarsh, seagrass beds and various biogenic habitats. Protection of these habitats and their stores will be critical.

Summary of knowledge gaps

While the understanding of climate change has significantly improved since the last assessment, many unknowns remain. The following knowledge gaps have been identified:

1. Understanding of mechanisms and processes linking the changes observed in the physical environment to individual organisms, their populations and the marine foodweb to ensure confident prediction of future change.

2. Distinguishing the long-term anthropogenic signal from the natural variability, especially of coastal systems.

3. The combined impact on species of climate stressors (deoxygenation, increasing temperature, increase in acidity) with loss of habitat, presence of contaminants and a change in pathogens.

4. The consequences of climate feedback mechanisms and their contribution to the rate of change in the physical characteristics of marine ecosystems.

5. The consequences of marine systems passing critical tipping points which may not be readily reversed. There is also lack of understanding as to the nature of these tipping points.

6. Being able to identify changes in marine ecosystems as a direct consequence of mitigating actions and the timescales over which such changes are expected to occur.