Indicators and trends

Monitoring climate change adaptation

climate change
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How is climate change impacting on Scotland's marine environment, infrastructure and industry?	Version
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Scotland's marine environment accounts for over 60% of the UK's total sea area, with approximately 48,000 km^2 of coastal waters and 49 estuaries covering an area of approximately 1000 km^2. Diverse and critical habitats within these areas means that it is estimated that Scotland's seas are among the most biologically productive in the world, supporting an estimated 6,500 species of animals and plants. Many of these are of significant regional or international importance for biodiversity conservation:

- Scotland is internationally important for breeding seabirds, hosting most of the UK population;
- Many seals, such as harbour and grey seals, are also residents here, spending time both at sea, and coming ashore to breed, moult or rest;
- In the past 25 years, 23 species of whales, dolphins and porpoises have been spotted around the Scottish coastline, of which 8, including minke and killer whale, are permanent residents;
- Scottish waters are also an important habitat for sharks, rays and skates, including the world's second-largest fish, the basking shark, which can reach 8m long;
- Deeper water habitats include species such as cold water corals, sea fan communities. Off the Sound of Canna can be found the largest aggregation of fan mussels in UK waters and one of the deepest and most unusual examples of a horse mussel bed.

This natural resource is also hugely important in sustaining many jobs and industries. Nearly all of the UK marine finfish aquaculture industry is concentrated in Scotland and is dominated by the production of Atlantic salmon with an estimated value of £677 million (2013); the shellfish industry in Scotland is comprised largely of mussel farms producing approximately one quarter of the UK total; and about 60% of the UK's commercial marine fish is landed in Scotland. Although fishing contributes a relatively small amount to the overall economy, in some regions of Scotland fishing is the mainstay of employment.

Assessing the effects of climate change on marine and coastal environments is complex. Primary physical consequences include: increasing water temperature; increasing ocean acidity; and increasing frequency and intensity of storms. These physical changes result in secondary physical effects by contributing to (along with non-climatic drivers) e.g. rising sea level; altered ocean circulation; and increasing ocean stratification.

These changes in the physical characteristics of Scotland's marine environment, will impact on biological diversity, associated marine industries and coastal infrastructure e.g.

- As species track suitable habitat due to changing water temperature, new species (some potentially suitable for commercial exploitation) will arrive and establish in Scottish waters, but there is also the possibility that existing species will be lost and that some new species will be invasive with consequential impacts on native biodiversity.
- Marine ecosystems are highly interconnected and direct impacts on one species will have knock-on effects further up the food chain e.g. altered abundance and distribution of plankton has reduced the availability of prey fish for some seabird species, with consequential impacts on their breeding success and survival.

- Changes in the abundance, range and seasonality of phytoplankton may result in an increase in harmful algal blooms (HABs) with consequential impacts on marine species and human health.
- As the oceans become more acidic, the ability for marine species to make strong shells and skeletons could impact on Scotland's important shellfish industry.
- Coastal flooding resulting from sea level rise and storm surges may damage coastal habitats through erosion and via intrusion of saltwater. Resulting flood and coastal erosion risk management strategies may lead to further changes in sedimentation processes.
- Increases in the intensity and/or frequency of storms will potentially impact on the deployment of fishing vessels and time spent at sea, increase risk of damage to equipment, and reduce the catchability of target fish

Adaptation options

The Scottish Government is "*committed to a clean, healthy, safe, productive and biologically diverse marine and coastal environment that meets the long term needs of people and nature*" and the Marine (Scotland) Act (2010) and the resulting National Marine Plan provides a framework which is intended to balance the competing demands on Scotland's seas. The National Marine Plan (published in March 2015), as well as considering how actions in the marine environment might help mitigate the degree of anthropogenic induced climate change, also considers the need for adaptation in order to take into account the effects of climate change. The core General Policies of the Plan, includes the need for decisions affecting the marine environment to include consideration of future climate change and provide effective adaptation strategies where appropriate. Regional Marine Planning Partnerships (with the first two for the Clyde and Shetland regions being set up in 2016) will also require the setting of regionally specific climate change objectives.

The Scottish Marine Protected Area (MPA) network forms part of the national strategy and covers approximately one fifth of Scotland's seas. An extensive and well managed network of MPAs has the potential to protect important marine habitats and species, and by doing so ensure the continued delivery of benefits to the whole of Scotland's marine environment, and continue to sustain marine industries and coastal communities. The MPA network provides:

- A network for facilitating the range shifts of populations;
- A focussed area for involving stakeholders and local communities in the dialogue on climate change impacts;
- Increased protection from human pressure which will facilitate monitoring of climate induced impacts and assessment of the effectiveness of management measures.

However, as the changing climate (along with other drivers) will alter the composition of habitats and species within the designated areas, management strategy will need to ensure that the legislation is being implemented in a way that is adaptive to climate change e.g.

- If the quality or composition of a feature improves or deteriorates, then management will need to adapt in response;
- MPA designations may need to be revised if features are lost;
- MPA boundaries may need to be revised in response to range shifts;

The wild capture fishing industry, is used to operating within the constraints of highly uncertain conditions of which climate change is just one. This uncertainty typically results in a forward view

within the industry of no more than one year ahead. In order to encourage a more long-term view, partnership working is already improving scientific advice and data collection. However, it will be necessary to increase the long-term view particularly with regard to: risk management of ports and processing sites; governance of fisheries (at both domestic and international levels); and fleet wide vulnerability. Given the nature of the industry and the variation in resources among stakeholders it will be necessary to ensure that adaptation can be implemented within individual management processes as well as encouraging a general industry-wide adaptation framework.

Improvements to scientific advice and data collection from both research and industry sources will create a more robust knowledge base and enable strategic long term planning. The most comprehensive assessment of the implications of climate change for the UK's marine and coastal waters is provided by the Marine Climate Change Impacts Partnership (MCCIP). MCCIP provides a co-ordinating framework (within the UK as a whole) for the communication of evidence and advice to policy advisors and decision-makers. However, there remains some significant gaps in knowledge (see table) both across the UK as a whole and specifically for Scotland which limit the ability to implement informed and effective adaptation policies and measures, as well as limiting the ability to monitor climate change impacts in the marine environment and evaluate management responses.

Significant marine knowledge gaps		
Risk	**Primary and secondary risks to physical marine condition**	• Changes in pH • Changes in salinity • Regional sea level change • Changes in transport of Atlantic water • Changes in strength and frequency of storms • Climate change influenced nutrient discharge to the sea
Impact	**Aquaculture & fisheries**	• Frequency and extent of HABs and plankton blooms • Impact on cultural aquatic species from changing pH, parasites and pathogens • Changes to time of spawning and growth rate due to temperature • Changes in fish catch latitude • Reduction in marine ecosystem integrity • Changes in safety and access for fishing vessels
	Nature conservation	• Extent and condition of coastal habitats • Distribution of marine invasive non-native species • Changes to distribution and condition of climate sensitive species • Loss of keystone species • Changes to migration of marine mammals
	Planning	• Extent and frequency of coastal flooding • Economic damage due to coastal flooding
Action	**Aquaculture & fisheries**	• Use of biosecurity measures to control/limit/eradicate marine invasive native and non-native species

		• Uptake of new technologies for environmentally sustainable commercial fishing and aquaculture • Occurrence of warm water species in landed catch • Level of use of selective fishing gear to improve targeting of species
	Nature conservation	• Management measures to improve ecological condition of marine waters • Uptake of advice and tools to help marine managers take informed decisions on adaptation
	Planning	• Evidence of adaptive management and changes to spatial policies in future Regional Marine Plans in response to changing environmental conditions • Coastal realignment • Coastal flood defences and natural flood management

MCCIP's assessment (2015) of the degree to which climate change is accounted for in marine biodiversity related legislation found that although climate change is rarely explicitly considered in the legislation, on the whole, mechanisms exist that could enable climate change issues to be addressed. However, in order for the objectives of the legislation to be delivered a number of key issues were highlighted:

- The need for risk assessments (in line with those which occur in the terrestrial environment) for marine protected areas taking account of the impacts of climate change on their designated features;
- Identify where species, communities and habitats are most at risk and prioritise effort to those areas;
- Ensure a flexibility in approach in order to maximise capacity to respond to climate-driven changes;

Mainstream the consideration of climate change when new legislation is developed or existing legislation updated.

What do the indicators tell us?

CXC's indicators focus on a number of aspects, for which appropriate and adequate data is available, of exposure and vulnerability of the marine environment and associated industries to climate change; critical resulting impacts; and highlight action to address these risks.

RISK due to changes in temperature and vulnerability of the marine environment to increased pressure due to climate change:

- *NM1 Changes in average sea surface temperature* shows that over the past 30 years surface waters around Scotland have warmed relatively rapidly, increasing by between 0.1 and 0.5 ˚C per decade (but this needs to be viewed in the context of spatial and temporal variability at smaller scales). The east coast has warmed at a slightly faster rate than the west coast over this period, and future projections show that this trend is likely to continue. These changes may lead to associated impacts on the distribution of HABs, key

commercial species and marine non-natives; damage to temperature sensitive aquaculture species; and altered migration patterns.

- *NB24 Proportion of water bodies not meeting Good Overall Status* includes coasts and estuaries and is intended as a measure of the resilience of Scottish coastal waters. Although there are many drivers which contribute to condition, improved status will be viewed as increased capacity of Scottish coastal waters to cope with the additional pressures from climate change. In 2014 approximately 3% of Scottish coastal waters and 14% of estuaries were assessed as at less than good status. Overall, coastal and estuarine waters are in better condition than freshwater bodies.

The IMPACT of changes in the occurrence, abundance and range of species and habitats of conservation interest; economically important or exploitable species; as well as potentially harmful species or events:

- *NM7 Number of Harmful Algal Blooms (HAB)* looks at the occurrence of potentially damaging phytoplankton species which are expected to see a northerly range expansion in response to changing sea surface temperature and altered seasonal stratification. There is currently a great deal of variability in HAB occurrence data and the role of climate change in these trends is uncertain. However, some key species have seen an increase around Scottish coasts with consequential impacts on native ecosystems and the shellfish industry.
- *NM21 Occurrence of warm water species in fish stocks exploited by Scottish fishermen: European anchovy; squid; red mullet; John Dory; European sea bass* shows there has been an increase in the occurrence of warm water species in UK waters as a whole, with squid and European anchovy showing a marked increase in abundance in Scottish waters. Other species which have shown an increase in occurrence in southern UK waters have also begun to appear occasionally in Scottish waters.
- *NB6a/ NB17a Abundance and productivity of migrating species: breeding seabirds* examines the abundance and productivity of breeding seabirds in Scotland to capture both seasonal and long-term effects. Both measures have seen an overall decline over the last 30 years for nine of the eleven species. The greatest declines have been recorded for Arctic skua, Arctic tern and black-legged kittiwake. With the exception of the black guillemot, all species have declined more rapidly in Scotland than in the UK overall, with the Northern Isles seeing the most serious declines. The reasons behind the declines is complex, involving a combination of climate change, changing food availability and the impact of invasive non-native species.
- *NM9b Frequency of escapes from fish farms due to weather* shows that a total of 2.5 million fish escaped from Scottish fish farms between 1995 and 2015 due to bad weather, of which 21% escaped during one storm event in 2005. Although escape events are less likely to be the result of weather than a non-weather cause, when they are, they are far costlier and on average resulted in six times more fish escaping. Whilst the North-East Atlantic is predicted to experience increased storm activity, there is currently no consensus on regional storm and wave projections. It will be necessary to analyse any change in storm events alongside an increase in industry awareness, recently agreed technical standards for marine cages and the, now mandatory, reporting of escapes.

Management and industry ACTION to improve the resilience of the marine environment and associated industries:

- *NM46 Change in the latitudinal distribution of industry sectors in response to shifting optimal conditions for species specific growth: aquaculture* will examine trends in the location of aquaculture sites over time in order to identify if the industry is adapting to

climatic range shifts. Projected temperature rise is likely to expose some species in Scottish aquaculture facilities to temperatures beyond their thermal optima and an overall northward shift in site placement may be required for the industry to adapt and maintain viable stocks.

Other relevant indicators

Coastal flooding events and their impact on the terrestrial built environment and infrastructure networks are captured by the narrative *Flooding and Infrastructure* and its associated indicators.

Climate change will impact on coastal habitats in a number of ways. Sea level rise and coastal erosion will cause inundation, more frequent and extensive flooding, alter the transport and deposition of sediments and saline intrusion- *NB10b Extent of key semi-natural habitats: coastal habitats* reports on the five coastal priority habitat types recognised by the UK Biodiversity Action Plan: 1) coastal sand dunes, 2) coastal saltmarsh, 3) coastal vegetated shingle, 4) maritime cliff and slopes, and 5) machair. The success of management of coastal and marine habitats and species of special interest is included in: *NB19 Proportion of notified habitats and species in 'positive' condition*.