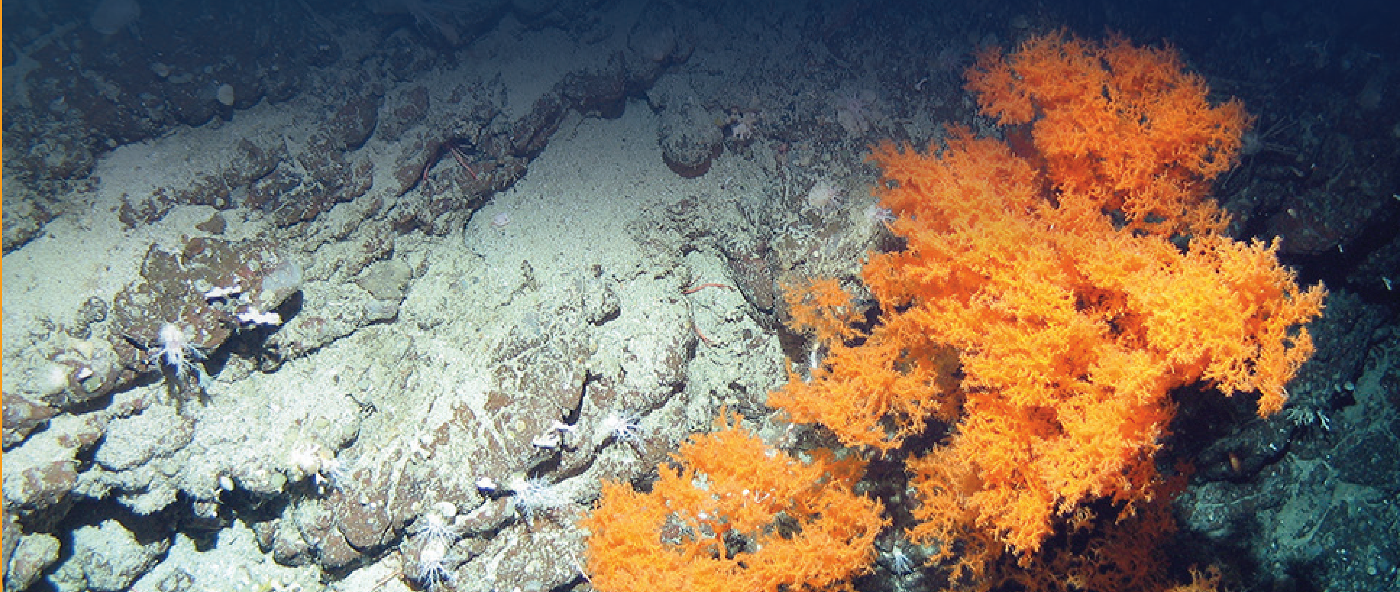
MCCIP Marine Climate Change Impacts Partnership

Climate change and marine conservation

Supporting management in a changing environment

Coral Gardens

- Significant changes in climate are projected to alter sea temperature, ocean currents, pH levels, water oxygen content and carbonate saturation of the deep-sea. These changes may have significant impacts on coral gardens through possible changes in abundance and distribution, community composition, coral physiology, fecundity, ecological function and associated fauna.
- Current understanding of how UK coral gardens may respond to a changing climate and its impacts on the environment is relatively limited, due to a lack of studies on the predominant species. It is still unknown whether climate change will affect the thermal and bathymetric range of coral gardens.
- Some evidence suggests that in higher sea temperatures, coral larvae may develop faster, meaning that larvae may not disperse as far, reducing connectivity and potential recruitment success between areas.
- Marine Protected Areas (MPAs) currently protect coral gardens at three of the five known UK locations. These are Hatton Bank candidate Special Area of Conservation (SAC), East Rockall Bank SAC and Anton Dohrn Seamount SAC. Wider management measures, such as fisheries closures, also help to support the protection of coral gardens both within and outside MPAs.
- In the future, changes to the MPA network could involve relocation of sites or amendments to boundaries to ensure MPA connectivity in a changing climate. It may also be possible to project the effects of climate change on ocean circulation and how this may affect coral larval dispersal, which in turn could be used to support decision making around protection and management.
- It is important that efforts are made to gather more information on the distribution, function and habitat roles of coral gardens in the UK. Specific research on the impacts of climate change on a range of cold-water coral species, in addition to existing studies on *Lophelia pertusa*, should be prioritised to better understand potential future responses.



2018
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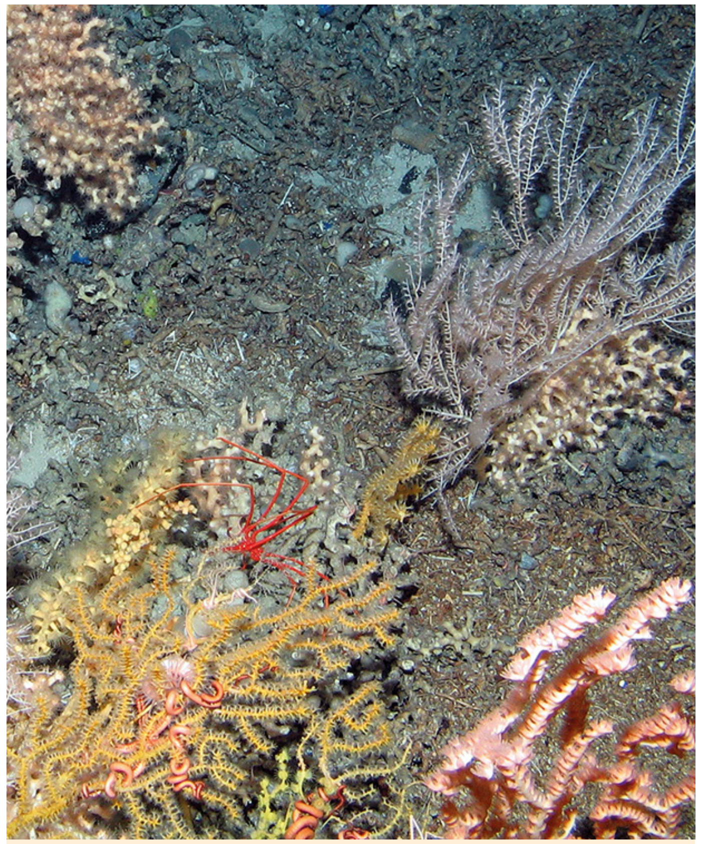
Coral Gardens

Coral gardens are dense aggregations of one or more coral species. They predominantly include soft corals, but can include individual hard corals, and contain noticeably denser groupings of individuals than found in the surrounding area.

In the UK, coral gardens occur in water temperatures of between approximately 3 and 8°C, and can be found on different types of substrata. Some corals need a hard surface to attach to when they first begin to grow from larvae, e.g. gorgonians; while others, such as sea pens and some bamboo corals, are found on softer sediment types. Coral gardens provide a home for many other animals such as basket-stars, brittle-stars and feather stars, bivalves, shrimp-like animals and deep-water fish.

Coral gardens are listed by OSPAR[a] as a threatened and/or declining habitat[1] and are also considered by the Food and Agriculture Organization of the United Nations as a Vulnerable Marine Ecosystem (VME)[b]. A UK definition[2] was developed, building on the OSPAR definition[1] to help identify coral gardens in the UK's deep-sea regions.

There are five confirmed offshore locations of coral gardens in the UK found across a depth range of approximately 500 m to 3000 m; Anton Dohrn Seamount, Deep Rockall Trough and the Hebrides Continental Slope[c], George Bligh Bank, Hatton Bank and Rockall Bank (see Figure 1). Within the UK, intra-regional variability is driven by environmental heterogeneity within seabed features. Differences in depth tend to correlate with changes in hydrodynamic regimes and substratum types, resulting in large differences in the composition and abundances of coral garden taxa[2].



Coral garden in Anton Dohrn Seamount SAC © JNCC.

Sand inundated rock with a blackbelly rosefish (*Helicolenus dactylopterus*), sea anemones (*Anthozoa*) and sponges (*Porifera*). East Rockall Bank SAC. © NOC

[a] OSPAR is the mechanism by which 15 Governments & the EU cooperate to protect the marine environment of the North-East Atlantic. Read more here: https://www.ospar.org/about

[b] See the definition as set out by the North East Atlantic Fisheries Commission on the FAO website: http://www.fao.org/in-action/vulnerable-marine-ecosystems/definitions/en/

[c] The verified locations in the Deep Rockall Trough and the Hebrides Continental Slope area are restricted to the deeper bathyal zone only but provide a unique sub-type only found at this site.

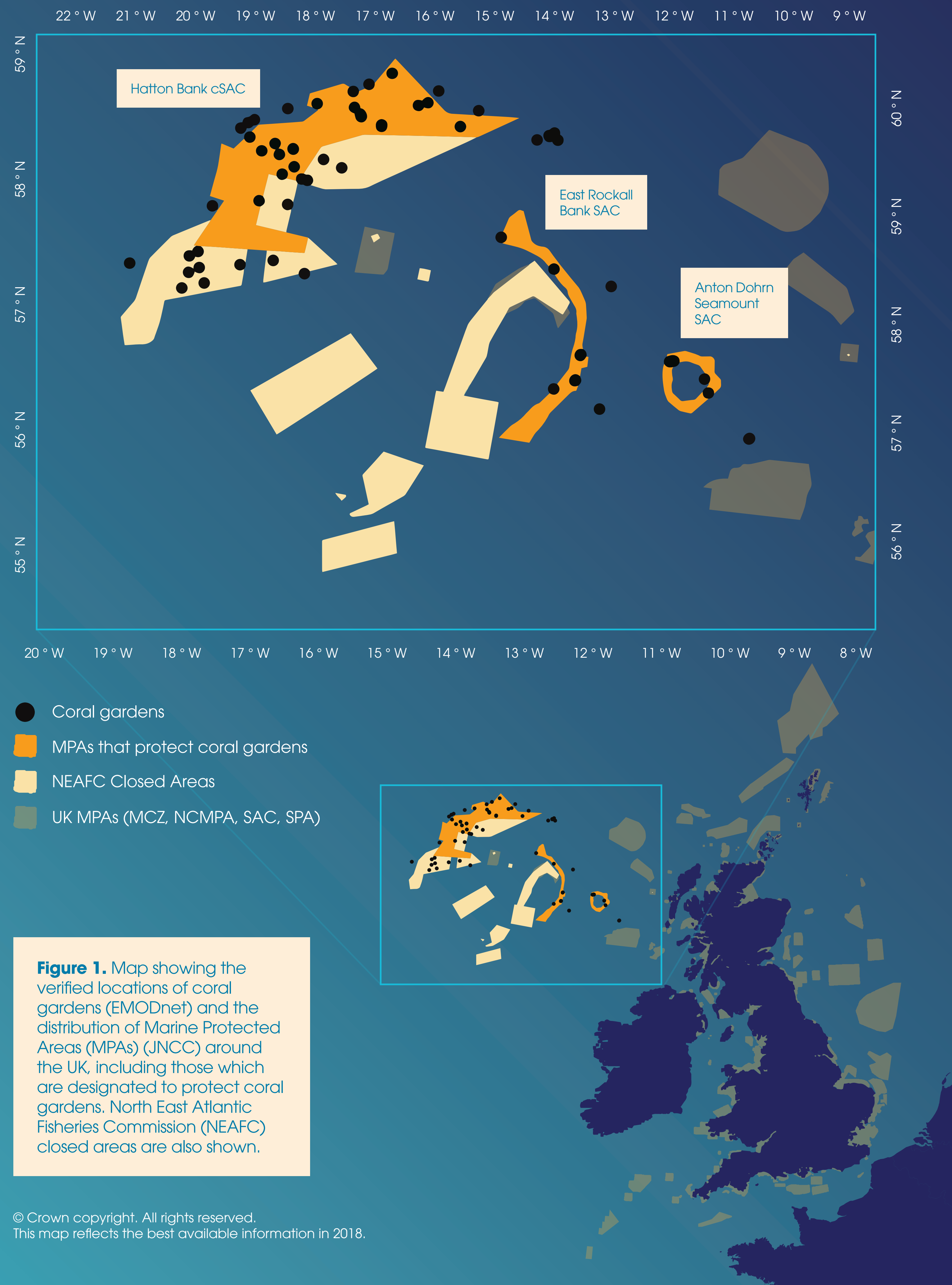


Figure 1. Map showing the verified locations of coral gardens (EMODnet) and the distribution of Marine Protected Areas (MPAs) (JNCC) around the UK, including those which are designated to protect coral gardens. North East Atlantic Fisheries Commission (NEAFC) closed areas are also shown.

This map reflects the best available information in 2018.

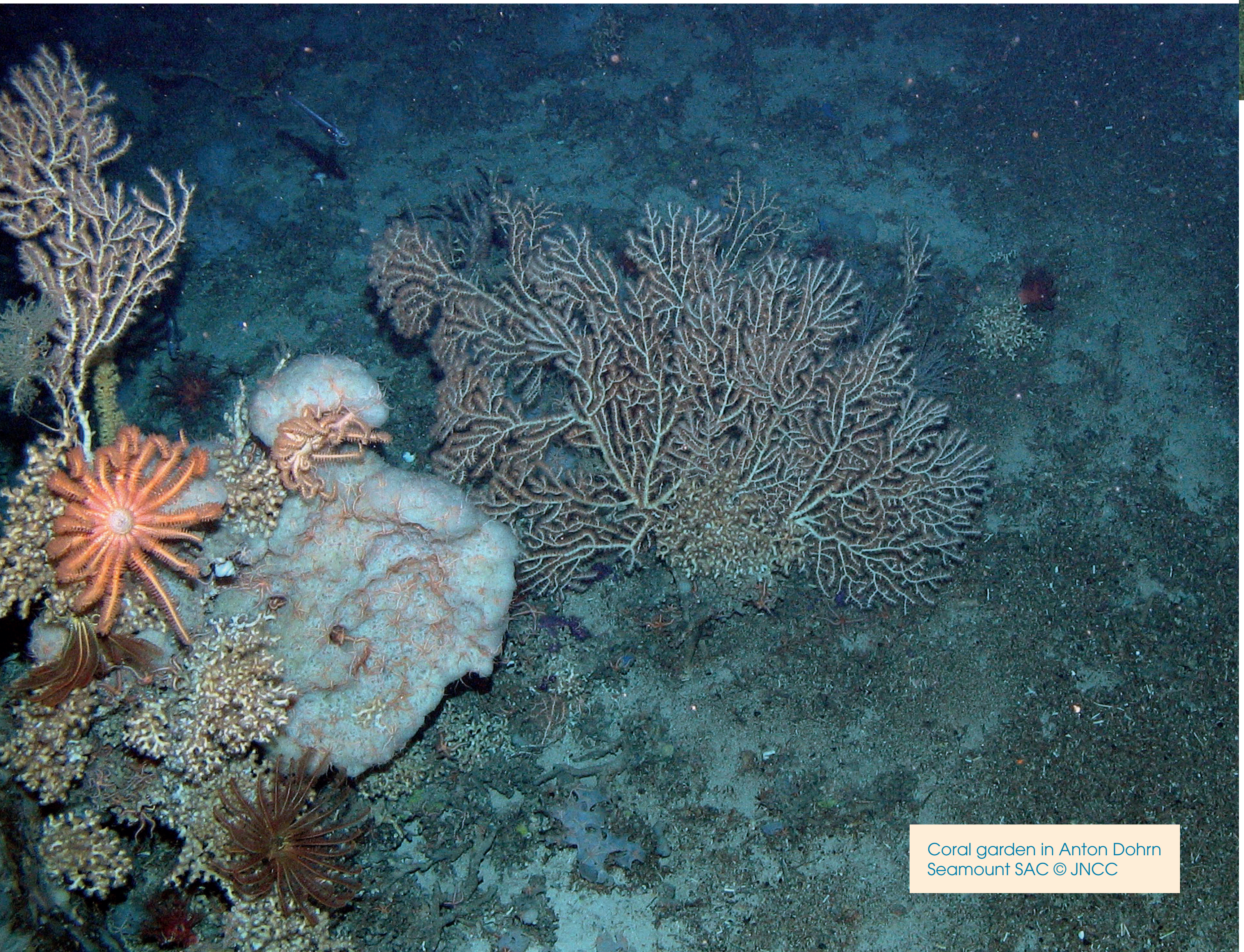
Scientific evidence for climate change impacts

There is a lack of direct evidence for climate change impacts on coral gardens, particularly on soft corals, such as gorgonians and black corals, due to their slow growth and lower recruitment rate.

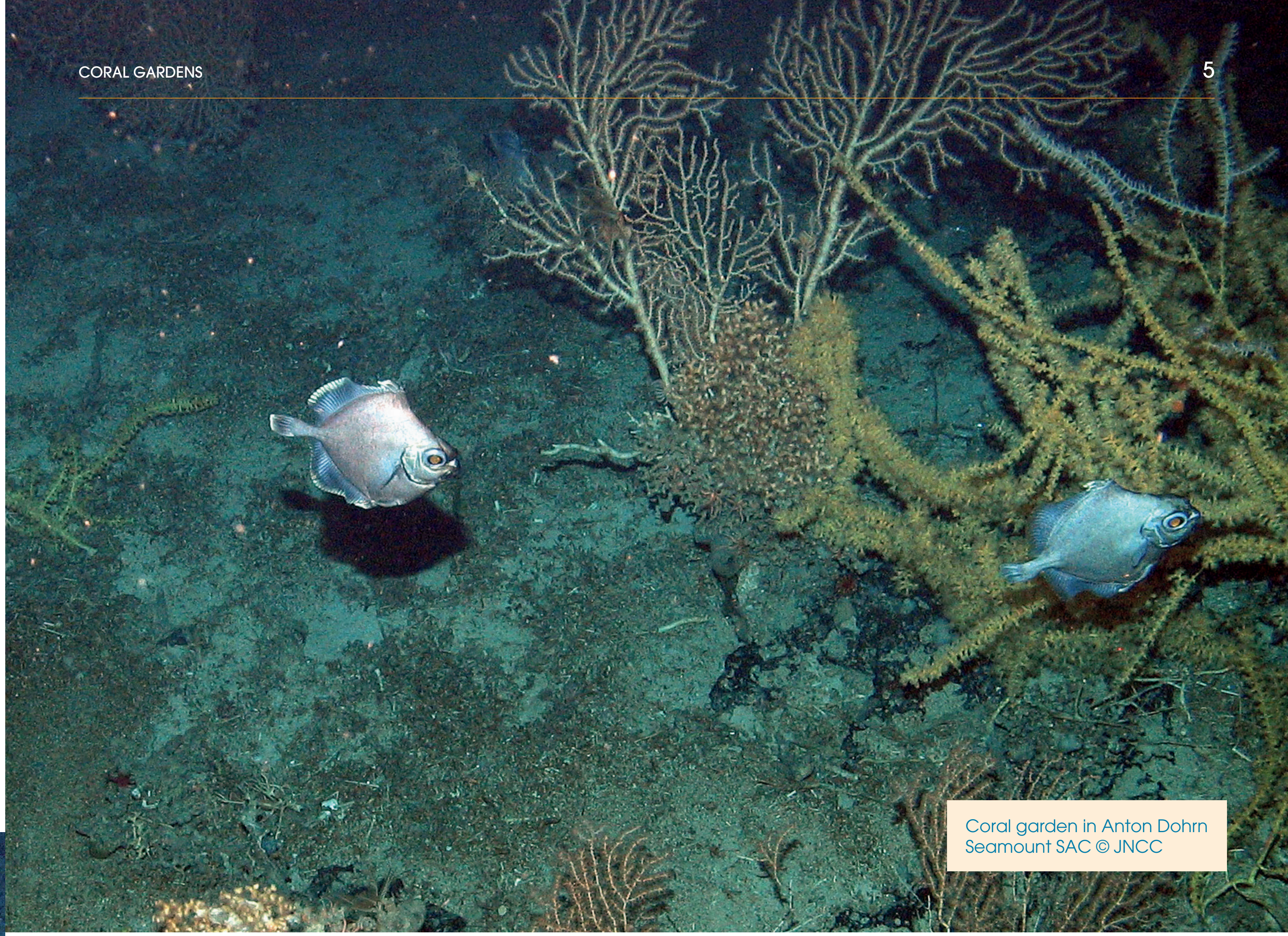
Research has concentrated on individual hard, cold-water coral species, such as the scleractinian *Lophelia pertusa*. Extrapolating from research conducted on individual cold-water coral species may increase our understanding of the potential risk that climate change poses to coral garden aggregations. Significant changes in climate are predicted to alter sea temperature, ocean currents, pH levels, water oxygen content and carbonate saturation of the deep-sea, which may, in turn, have significant effects on coral gardens[3,4,5].

Presently, it is still relatively unknown as to how climate change may impact coral gardens but these changes to the marine environment could potentially result in changes in abundance, distribution, thermal and bathymetric range, community composition, coral physiology, fecundity, ecological function and associated fauna.

Sea temperatures in the north-west of the UK are likely to increase by up to two degrees by the end of the century[7] and these changes may affect deep sea ecosystems. An increase in water temperature could result in cold-water coral species being replaced by coral species more tolerant to warmer waters, causing changes in the composition of coral garden assemblages. Evidence suggests that in higher sea temperatures, coral larvae may develop faster, meaning that larvae may not disperse as far[3,4], thereby reducing connectivity and potential recruitment success. If dispersal distances are reduced, this may also change where coral gardens occur and reduce the likelihood of larvae reaching suitable ground for settlement. Planktonic distribution is also likely to change, ultimately changing the food supply reaching coral gardens, with some areas receiving decreased levels and different plankton species[8].



Coral garden in Anton Dohrn Seamount SAC © JNCC



Coral garden in Anton Dohrn Seamount SAC © JNCC

Changes further afield could also impact waters in the UK. Changes in water temperature can induce changes in ocean currents, and have a significant effect on corals globally. There is a correlation between the effect of atmospheric-driven changes in ocean circulation and coral larval dispersal. There is evidence that during a negative (cold) North Atlantic Oscillation (NAO), modelled simulations showed larvae of the cold-water coral species *L. pertusa*, exhibited a fragmented dispersal, resulting in reduced connectivity between sites. Larvae travelled to different geographic areas dependent on the phase of the NAO. This suggests that atmospheric cycles can profoundly impact the connectivity of corals, and that positive and negative NAOs are important for connectivity to different areas across time[9].

Climate change is also likely to result in a decrease of oxygen within the ocean, especially in the deep sea and could result in the formation of 'dead zones'[1]. Evidence suggests that conditions in the deep sea will become generally warmer and more acidic, with lower oxygen and food levels, all of which are harmful for coral gardens[5]. Although some species may be able to tolerate or adapt quicker to such changes, many cold-water corals cannot tolerate low oxygen levels, and such changes may lead to the local extinction of certain species, potentially resulting in the thinning and complete loss of coral garden aggregations at the local scale.

Short-term exposure to high levels of carbon dioxide will cause a reduction in sea surface pH, leading to changes to the carbonate chemistry and a decline in the calcification of the hard coral components of coral gardens[5]. Ocean acidification is causing the aragonite saturation horizon (ASH) to shoal, increasing areas of aragonite undersaturation[10]. This exposes deep-water corals to waters that are corrosive to hard coral skeletons[11] and restricts the maximum depth at which hard corals can survive. Model projections of the shoaling ASH reveal that north-east Atlantic coral reefs are at risk of exposure to corrosive waters[10,13,14]. Thus, coral gardens may also be at risk of exposure to these corrosive waters, which could, in turn, alter the aggregation's composition or result in loss. If the coral species making up the coral garden were to change in response to climate changes, this may have significant implications for the functional role they provide to associated species. For example, the deepwater skate *Bathyraja richardsoni* have been found to attach their eggs to cold water corals within coral gardens[15]. Therefore, if this type of coral was to be lost from a coral garden assemblage, this could have an impact on the successful reproduction of skate.

What is already being done to support the protection and management of coral gardens in a changing climate?

Appropriate management of the UK's coral gardens in relation to potential pressures is especially important because the impacts of climate change will be heightened when combined with other stressors.

Three of the five known locations where coral gardens occur in the UK are afforded protection through MPAs: Anton Dohrn Seamount; East Rockall Bank; and Hatton Bank[d] (see Figure 1).

All three MPAs were designated to protect features, which include coral gardens. Conservation objectives set out the desired state for the protected features of an MPA and are used to guide management of the site. Fisheries management measures are being established for Anton Dorn Seamount Special Area of Conservation (SAC) and East Rockall Bank SAC, which will be managed under the EU Common Fisheries Policy.

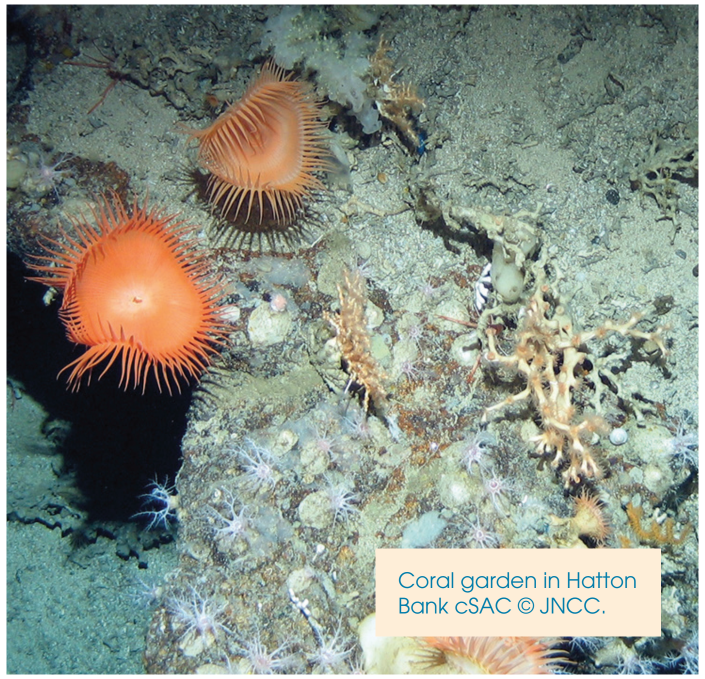
The full extent of Hatton Bank SAC has been closed to demersal fishing since 2013 under a North East Atlantic Fisheries Committee (NEAFC) Recommendation to protect VMEs[e]. Whilst licensable activities such as oil and gas exploration and production do not take place within any of the MPAs, any future proposals would need to go through a consenting process and comply with relevant legislation.

Wider management measures, such as the NEAFC fisheries closures, that are in place in the Hatton Bank and Rockall areas, help to support the protection of coral gardens both within and outside of MPAs (see Figure 1)[4]. Furthermore, the recently introduced EU Regulations on fishing for deep sea stocks[f] sets out new rules to protect VMEs, such as coral gardens. This provides a depth limit of 800 m, beneath which, bottom trawling is not permitted, and lays down separate rules to protect VMEs below 400 m. These measures should help to protect most coral gardens in UK waters from pressures associated with this type of fishing.

What management measures for coral gardens could also increase resilience to climate change?

In the UK, an adaptive management approach is being applied to MPAs, which could allow adaptation of boundaries and management to climate change[g].

Connectivity between MPAs is essential for the resilience of the communities that they protect and to support an ecologically coherent MPA network[16,17]. In future, changes to the MPA network could involve relocation of sites or amendments to boundaries to sustain MPA network connectivity in light of climate change. It may be possible to project the effects of climate change on ocean circulation (e.g. NAO variation) and how this could affect coral larval dispersal and connectivity between coral garden locations. This means that we could potentially identify areas of the ocean that, if protected, would contribute to supporting connectivity for this feature within the MPA network. Similarly, fisheries closures for the protection of VMEs could potentially be amended under variable climate scenarios or newly identified VME locations.



Coral garden in Hatton Bank cSAC © JNCC.

[d] Further information on these offshore MPAs can be found on the JNCC website, available here: http://jncc.defra.gov.uk/page-4524
[e] Recommendation on the protection of vulnerable marine ecosystems in the NEAFC Regulatory Area. Recommendation 19: 14 amended by Recommendation 09: 2015. Available online here: https://www.neafc.org/system/files/Rec_19-2014_as_amended_by_09_2015_fulltext_0.pdf
[f] EU regulations on fishing for deep sea stocks. Available online here: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R2336&qid=1483951220985&from=EN
[g] As set out in the UK Marine Policy Statement and the Marine and Coastal Access Act 2009.

What wider management options could feasibly be considered?

Owing to the dispersal routes and distances that coral larvae can travel[3,4,9], management may need to be considered on an international transboundary scale.

Models show that the Porcupine Seabight in Irish waters may act as a source of coral larvae for UK waters and Hatton Bank may be an important source for the Atlantic High Seas[9]. As such, protecting areas of cold-water coral (which make up coral gardens), should be an international management project, involving all relevant stakeholders. Contracting Parties of the OSPAR Convention (to which the UK is a signatory) have made a set of recommendations for the measures that could be taken to improve the conservation status of this habitat within the north-east Atlantic. OSPAR Recommendation 2010/09[1] aims to strengthen the protection of coral gardens, proposing measures such as considering the introduction of national protective legislation; assessing existing management measures; and investigating the distribution, quality and extent of coral gardens. These recommendations will help to encourage restoration and support a better understanding of the features, conservation and resilience to pressures from human activities and climate change at the north-east Atlantic scale[1].

In addition to existing management mechanisms that may afford direct protection to coral gardens, certain ecological mitigation measures could be introduced to support their conservation. Ecological mitigation could include innovations such as coral recruitment panels. Measures such as this would increase the amount of structures to which larvae can attach and develop small communities, acting as stepping stones to facilitate connectivity.

Some cold-water coral species, found in coral gardens, are known to colonise oil and gas infrastructure. Offshore industries have, therefore, a significant role to play in contributing to their protection; for example, by implementing monitoring programmes that contribute to a better understanding of the effects of climate change on these species.

Coral garden in Hatton Bank cSAC © JNCC.

Practical actions to support management

The following steps align with some of the proposals set out in the recommendations made by OSPAR and are a continuation of work already underway.

1. Gather more information on the distribution, function and habitat roles of coral gardens within UK seas. Ensure any new locations of coral gardens that are identified are protected from damage.
2. Investigate and map distribution of coral gardens within the UK seas using modelling and data from direct surveys, alongside climate data in the same region.
3. Undertake research into the effects of climate change on a range of coral garden species. This could include controlled experiments under different climate scenarios to increase understanding of coral gardens and evaluate key abiotic/biotic proxies for measuring species success or sensitivity, such as development rates, fecundity, reproductive success, physical health, weather patterns, dispersal distances, pH and temperature to determine the extent of pressure effect.
4. Identify any pressures that are currently impacting the feature and potential future threats. Work with offshore industry to strengthen the cross-sectoral working, in particular, oil and gas to map coral garden occurrences and study sensitivities to the adversity of drill cuttings and dispersants.
5. Monitor known locations of coral gardens in the UK using relevant indicators and use data gathered to undertake condition assessments.
6. If required, adapt management practices based on findings from monitoring and research and create appropriate mitigation methods, then enforce and monitor. Conduct evaluation on whether mitigation has been successful.
7. Communicate the importance of coral gardens to the public to increase awareness.

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Front page image: Black coral (*Leiopathes sp.*) on rock with sea cucumbers (*Psolus squamatus*) on deep-sea bedrock: Annex 1 Reef, DECC SEA programme