MCCIP Marine Climate Change Impacts Partnership

Climate change and marine conservation

Supporting management in a changing environment

2018

Horse Mussel Beds

- The historical extent of horse mussels has reduced around the UK in recent years.
- Horse mussel beds are potentially threatened by several climate change stressors including rising seawater temperatures, ocean acidification, changes in wave exposure and ocean currents.
- A predictive habitat modelling study suggests that horse mussel beds may lose all of their most suitable habitat within UK waters by 2080 under a medium emissions climate change scenario.
- Horse mussel beds are sensitive to a range of human activities, including use of towed demersal fishing gear, scallop dredging, cable laying and other activities which cause seabed disturbance.
- Reducing or removing pressures associated with human activities is likely to be the most effective method of increasing the resilience of horse mussel beds to climate change.

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Horse mussel beds

The horse mussel (*Modiolus modiolus*) is a large, long-lived, slow-growing bivalve mollusc typically found in temperate subtidal waters of the Northern Hemisphere, including the UK.

Horse mussels are capable of forming dense aggregations, attaching themselves, via secreted byssus threads, to each other and to the substrate. Over time the build-up of live mussels, shell material, faeces and pseudofaeces can stabilise the substrate and create persistent structures known as reefs or beds[1,2]. The structural complexity of the beds and increases in organic material can increase local food and habitat availability, making beds capable of sustaining diverse biotic communities[3]. Species found on mussel beds include barnacles, red seaweeds, crabs, scallops, whelks, brittlestars and starfish.

The beds may also be important for some commercial species including whiting, poor cod, queen scallops and common whelks[4,5,6].

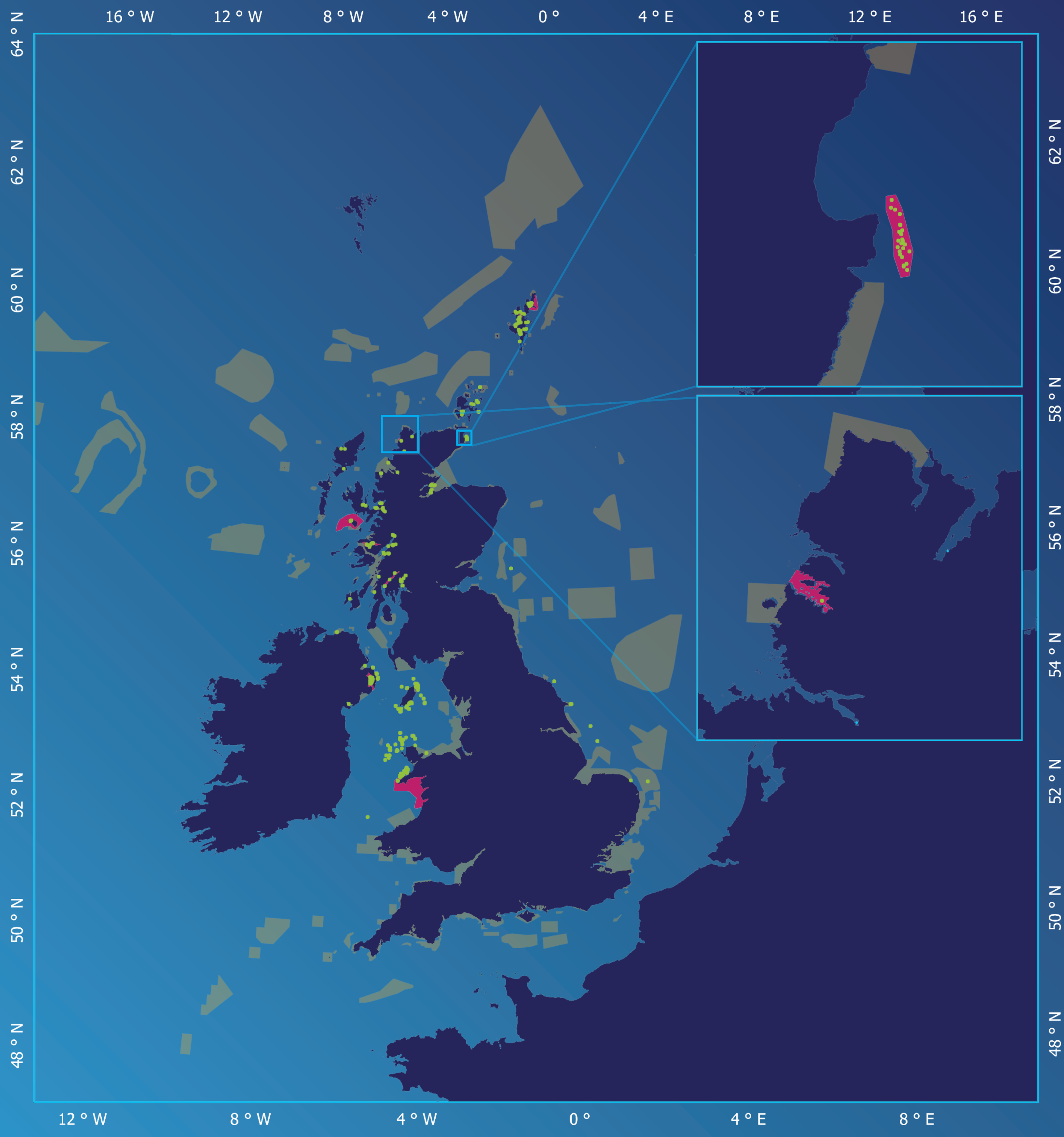
Horse mussel beds can range from clusters of a few individuals up to extensive beds of dense aggregations, with 100s of individuals per square metre, spread over several kilometers[7,8]. Beds are sensitive to activities such as towed demersal fishing[9,10], and potentially vulnerable to a range of climate change pressures including increased sea water temperature, which may alter their habitat range[11] and ecosystem functioning[12]. This could not only affect the horse mussels themselves but also the many species that use the beds for food and shelter. Beds are listed as a Priority Marine Feature in Scotland, as a Habitat of Principal Importance in England and Wales and as a feature of Marine Protected Areas throughout the UK. They are also on the OSPAR list of threatened or declining habitats.

Map of current feature distribution

In the UK, horse mussel beds have been documented in coastal areas from northern Scotland as far south as the southern Irish Sea, including the Shetland Isles, Orkney Isles, mainland Scotland (predominantly west coast), Northern Ireland, and the Lleyn Peninsula in Wales (Figure 1)[13]. They can occur at depths from the low intertidal zone to approximately 280 m[9] but are most commonly found subtidally between 5-70 m[13].

To be classified as a reef under the European Habitats Directive there needs to be live horse mussels individuals to be present, the associated bed biota to be distinct from the surrounding habitat and the distinct region containing horse mussels to be greater than 25 m^2 in extent[2]. However, frequent small clumps of horse mussels which influence ecosystem functioning can also be classed as beds for conservation and management purposes[13].

A sunstar on a horse mussel bed at Loch Creran
Graham Saunders © SNH



Horse mussel records

MPAs that protect horse mussel beds

UK MPAs (MCZ, NCMPA, SAC, SPA, SSSI)

Figure 1. UK map showing verified recordings of horse mussels (OSPAR), and the distribution of Marine Protected Areas (MPAs) including those which are designated to protect horse mussel beds (JNCC).

This map reflects the best available information in 2018.

Scientific evidence for climate change impacts

Emerging research, and recorded impacts on similar species, suggest horse mussel beds may be threatened by a number of climate change stressors.

Horse mussels exhibit many characteristics which make adaptation to changing conditions difficult. This includes late reproductive maturity (5-6 years), low larval settlement success and a sporadic reproductive output[14]. Because the species predominantly inhabits subtidal environments that are characterised by relatively stable conditions, it may be less able to deal with a changing environment.

Climate change issues which may impact horse mussel beds include sea water temperature increases, changes in currents, increased occurrence of hypoxic events and ocean acidification. These threats could result in a northerly retreat and overall decline in the extent of mussel beds in UK waters[9].

As horse mussel beds are scarce south of the Irish Sea, their distribution is thought to be correlated with water temperature, indicating a potential vulnerability to rises in sea water temperature[15,16]. Climate projections for the UK suggest a sea surface temperature rise of between 1.5 - 4°C over the 21st century[17]. Increasing temperatures could affect the health, recruitment success and distribution of mussel beds, ultimately reducing the extent of the UK population[18,19]. A predictive habitat modelling study suggests that horse mussel beds may lose all of their most suitable habitat within UK waters by 2080 under IPCC medium emissions climate change scenario A1B[19].

Impacts of ocean acidification have been found in other bivalve species including Pacific oysters (*Crassostrea gigas*) and the blue mussel (*Mytilus edulis*)[21]. These studies found significant changes in shell morphology and thickness occurred under reduced pH, affecting the bivalves' ability to resist predation. However, coinciding factors such as temperature and food availability can also have a strong influence on shell strength and predation resistance. Fertilisation, larval development and settlement are also negatively affected, further reducing recruitment and recovery[20,21].

Climate change may also alter oceanic circulation currents and change the frequency and severity of storms and waves. High flows can cause inhalant siphon closure[22], possibly impacting feeding ability. Increased tidal flow and wave exposure could also lead to an increase in byssus thread production[23], potentially reducing energy available for growth and reproduction. Conversely, reduced flow rates can reduce food availability and increase the frequency and strength of hypoxic events[24]. For example, horse mussel reefs located in sheltered (i.e. reduced wave energy and water exchange) areas such as sea lochs may be increasingly exposed to the combined effects of warming and hypoxia.

Larvae may be impacted by changes in ocean circulation, leading to impacts on distribution as well as possible mismatches with food availability[25]. Warming sea temperatures may reduce the larval pelagic stage and affect dispersal potential.

What is already being done to support horse mussel beds in a changing climate?

Within MPAs, fishing with demersal mobile gear, and marine and coastal development may be regulated or excluded to protect horse mussels. Potential impacts on beds within Natura 2000 MPAs are considered through Habitats Regulations Appraisals. Here, the regulator must either confirm that proposals will not affect the integrity of a site or prove a case that the development has imperative reasons of over-riding public interest.

The inclusion of horse mussel beds in the Marine Strategy Framework Directive provides further protection within one third of a nautical mile from the coast. In Scotland, Priority Marine Features are given policy protection from activities that would result in a significant impact on their national status (National Marine Plan Policy, GEN9). Environmental Impact Assessments are also completed to assess whether activities will impact on the feature. Specific policies are included in some regional management plans to guide development and damaging activities away from sensitive areas.

Action is also needed outside of MPAs where beds occur. In Wales, bye-laws have been used to create an exclusion zone around an area of reef outside of their SAC series to prevent fishing. However, it is often hard to police illegal activity so damage can still occur.

What management measures for horse mussel beds could also increase resilience to climate change?

Due to their slow to non-existent recovery after impacts[9], reducing or removing pressures associated with human activities is likely to be the most effective method of increasing the resilience of horse mussel beds to climate change.

The inclusion of horse mussel bed protection in regional marine plans will help ensure that potential impacts are considered when planning marine development and/or activities within or outwith MPAs.

Additionally, marine spatial planning should include provisions that reduce existing pressures to which the habitat/species has a high sensitivity (e.g. seabed disturbance and siltation brought on by bottom-towed fishing equipment)[9]. The exclusion of mobile bottom fishing gear on mussel beds could possibly improve some fisheries, e.g. scallops and whelk as well as help protect the beds' role as a nursery site for other commercially important species[26].

The connectivity of populations is an important aspect to the resilience of a species under pressure from climate change[27].

It has therefore been suggested that maintaining and enhancing connectivity should be considered when designing MPA networks to facilitate replenishment and recovery from disturbance, particularly under climate change[29], given the importance of connectivity in maintaining existing populations.

Genetic connectivity analyses were carried out for individual horse mussel beds in Scotland[29] and within the Irish Sea[19]. Generally, results indicate moderate-high levels of genetic connectivity between sampled populations. Coupled particle tracking and hydrodynamic modelling partially supports these results, indicating that there is connectivity amongst horse mussel beds on the west coast of Scotland and Orkney. Further work is required to explore the complex connectivity of these populations and whether additional areas are acting as stepping stones[30]. What is clear is that any disruption to genetic connectivity through habitat fragmentation and/or changes to oceanic current regimes may lead to a loss of the habitat, or lack of recruitment, threaten ecosystem integrity and functions and possibly result in inbreeding[31]. Therefore, potential barriers to, or disruptions in, gene flow must be considered when developing the MPA network, undertaking marine spatial planning or developing management measures.

Brittlestars with horse mussels and green urchins at Loch Creran. Graham Saunders © Marine Scotland

What wider management options could feasibly be considered?

Ecosystem services and natural capital

Using ecosystem services and natural capital in marine planning may help highlight the value of healthy horse mussel beds. This includes their ability to act as a carbon sequestration and storage site, as well as their value as a nursery site for marine species with commercial value[32,33].

Translocation

Studies on Strangford Lough horse mussel populations indicate that natural recovery may not be feasible for many populations and that some level of direct intervention may be required for recovery to occur[10]. A horse mussel translocation study undertaken in Strangford Lough made assessments of suitable bed design, survival of translocated individuals and on-site faunal succession. Initial results showed promise that translocation could be effective in repairing damaged beds or establishing new beds. This may assist northward migration or establishment in areas of cooler, deeper water which can still provide a suitable habitat[34].

Refugia/ark sites

Climatic envelope modelling of projected future conditions, connectivity analyses, vulnerability analyses and surveys of horse mussel beds could aid in identifying beds which have remained relatively intact, are likely to be less affected by climate change, and support other beds (e.g. via larval supply). These zones could receive greater protection and act as ark sites or refugia, providing a greater chance for the species to persist or adapt to climate change.

Monitor/control of damaging invasive species

Horse mussel beds could see an increased threat from invasive non-native species such as the slipper limpet (*Crepidula fornicata*) which can smother and out-compete native species. Whilst horse mussels currently exist further north than *C.fornicata*, if warming temperatures continue to facilitate the spread of *C.fornicata*, they could become more of a threat to horse mussels. Control methods have been attempted on *C. fornicata*. Whilst the spread of this particular species is likely uncontainable there would be benefits in maintaining vigilance against the emergence of new invasive species which may yet appear and establish, by preventing their spread and though improved biosecurity methods.

Identification and protection of beds important for recruitment

Genetic analysis may be used to identify horse mussel beds that are genetically diverse and genetically connected to other beds. Protection to retain these beds would help in maintaining colonisation levels and in the repair of damaged beds through recruitment. Maintaining healthy gamete source sites and identifying and protecting any networks of beds would also aid in reducing "Allee" effects (i.e. a high population density maintains high growth rates).

Research requirements

There are research programmes underway to further identify pressures and assess possible responses to protect horse mussel beds from climate change. Further research is required in the following key areas:

- The impacts of multiple stressors on horse mussel beds to understand what degree of change they can tolerate. For example, there is emerging evidence that hypoxic events can reduce tolerance to other stressors such as increases in sea temperature.
- The impacts of climate change on larval development and settlement, to aid in determining species' sensitivity, connectivity (via larval distribution models) and distribution potential, and contribute to restoration efforts (although reducing climate stressors will still provide the best chance for successful restoration).
- Investigating the specific physiological responses (thermal limits, stress response) and genetic structure of populations.
- Determining how terrestrial inputs affect horse mussel health, including for example, organic matter, and increased freshwater run-off.
- Localised assessments of climate stressors may be required to ensure management responses are appropriate to the severity of impacts being experienced at each site.
- Research into the impacts of climate change stressors on ecosystem function may encourage protection of the beds through increased awareness of their economic benefits.
- Research into natural recovery and restoration following disturbances such as trawling. This could help determine the level of aid that may be required to help beds recover, either naturally or through artificial restoration or translocation where impacts are more acute.

Practical actions that could support management

The process outlined below could be conducted for an individual site, for the horse mussel beds within existing MPA networks or across wider seas. The most realistic management for beds in a changing climate is one that is focused on managing pressures.

Management should focus on reducing current and future human pressures to the habitat in order to increase resilience to climate change (see table below). Restorative measures should be considered in certain cases following protection.

Stage	Process/Questions
1. Background Define the feature	a) What is the feature? its role and function. b) What is the management objective? Maintaining overall ecosystem structure and function, etc. c) What is the spatial/temporal scale being considered? Determine the extent of the management area and the time scale for management.
2. Vulnerability assessment Identify the existing non-climate change threats to the feature	a) What is the feature condition? Are there any trends from monitoring? Is it favourable or declining? b) For the pressures that horse mussel beds are sensitive to (see Feature Activity Sensitivity Tool (FEAST)/Marine Evidence Based Sensitivity Assessment (MarESA) are they exposed to these at the locations considered? c) Determine vulnerability based on the above (Vulnerability Assessment). d) What is the frequency of the threats (Frequent/Rare). e) Are there synergistic effects between pressures that we know about? (e.g. temperature and hypoxia etc.)
3. Scope for change	a) Are there alternative states which provide similar functions (and would this be acceptable)? What about other biogenic reefs? b) Are any changes in structure/function acceptable?
4. Increasing resilience through reducing current pressures	a) Are the pressures to which the horse mussel bed is vulnerable currently managed and is this adequate? b) For those that aren't managed, which should be prioritised? c) Identify mechanisms and requirements to address the above.
5. Identification of MPAs and locations more at risk from climate change	Can we use climate envelope modelling and reviews of vulnerability assessments to identify which sites are likely to be impacted in the future?
6. Monitoring	Any monitoring strategies established to take into account the following parameters: • Adopt a risk-based approach to prioritisation of locations including sites under low pressure and sites under high pressure, including from other pressures such as developments, fishing and pollution etc. • Monitoring should take place across the species climatic range to detect possible shifts in populations. • Monitoring locations should encompass a variety of horse mussel bed types, based on biotopes and substrates. • Monitoring should where possible make connections between cause and effect to inform adaptive management. • Monitoring may require some level of molecular biomarker testing such as oxidative stress testing. • Monitoring recruitment would help improve our understanding of the impacts of climate change on larval development and settlement.

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Front page image: Close up of a gaping horse mussel at Annat Narrows, Lochs Eil and Linnhe. Graham Suanders © Marine Scotland