MCCIP Marine Climate Change Impacts Partnership

Climate change and marine conservation

Supporting management in a changing environment

Seagrass (*Zostera* spp.)

- Climate change impacts on sea temperature, sea level, storminess and rainfall patterns, as well as ocean acidification, could affect seagrass species.
- These effects could be both positive and negative, and need to be understood in the context of other human pressures (e.g. eutrophication, siltation and physical disturbance).
- Seagrass productivity, growth and flowering rates, and habitat distribution are all likely to be affected.
- There are potentially complex interactions between climate effects on species that rely on seagrass meadows and the rate of response of seagrass to climate change.
- Whilst there are significant risks to habitats there is potential for an increase in range of intertidal and subtidal seagrass.
- Management measures which reduce wider pressures can be used to increase resilience to climate change, but further proactive measures could be put in place. Modelling could be used to project suitable areas for colonisation and areas at particular risk. Wider management measures include protecting whole sites rather than features, and management of adjacent sites and ecosystems.

2018

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Seagrass

Seagrass is a true marine flowering plant and can form extensive meadows in coastal regions around the world. In the UK, seagrass (*Zostera*) species are widespread but are considered to be nationally scarce with a patchy distribution.

Intertidal *Zostera noltii* beds are often found in muddy sediments. *Zostera marina* (eelgrass) are found subtidally, typically down to 4-5m depth, in soft sediments of muddy-sand to fine gravel. Both species are found at sites sheltered from significant wave action and siltation, in brackish or fully marine conditions and exhibit large seasonal changes in cover and biomass[1]. Seagrasses are amongst the planet's most effective natural ecosystems for sequestering (capturing and storing) carbon; but if degraded, they could release stored carbon into the atmosphere and contribute to global warming[2].

Seagrass leaves slow water currents aiding settlement of particles and larvae, and improving water clarity, while the rhizomes (which produce roots and shoots) stabilize the sediment. The leaves provide a surface of attachment for a number of species and the canopy provides shelter, as well as acting as a valuable nursery for commercially important fish species. When exposed, they are an important food resource for wintering wildfowl[3,4].

The beds provide habitats for species of conservation importance such as stalked jellyfish and seahorses[5]. The detritus from *Zostera* beds can provide an important source of organic matter for surrounding coastal habitats[6,7].

Overall, *Zostera* beds can increase the biological diversity of an area and are considered of economic and conservation importance[8]. Following the large scale decline of subtidal seagrass in the 1930s due to a wasting disease, recolonization has not led to an extent and distribution equal to the historical levels[9].

Scientific evidence for climate change impacts

Seagrass is sensitive to disturbance from human activities (Table 1) and OSPAR[9] report that seagrass is under threat in all areas where it occurs and is declining across the Greater North Sea.

Survival and health of seagrass is linked to changes in adjacent land as well as adjacent waters[10]. Eutrophication from increased nutrient input and smothering from increased sedimentation are the main threats to seagrass as a result of human activities[8,11].

Impacts may be reversible if the activity is of low intensity and short duration and conditions may return to those found before the activity. If rhizomes fragment or seeds remain in the locality, rapid recovery can occur. If there is a permanent change to the sea-bed, water clarity or current or sediment regime and/or entire beds are lost, re-colonization is unlikely or may take a considerable time[9]. These permanent changes may occur in response to the human pressures listed in Table 1, but the effects of climate change can also prompt additional impacts (Table 2).

Climate change is affecting seawater temperature, salinity, sea level, rainfall and weather patterns with potentially wide-ranging biological effects. Globally averaged ocean temperature anomalies, relative to a 1971–2010 mean, reveal warming is occurring at a rate of 0.11 (0.09 to 0.13) °C per decade in the upper 75 m[14]. This seemingly small change could be occurring at a faster rate than seagrass species can respond to. In addition, the larger seasonal change in air temperatures may cause further increases in the temperature of shallow waters or intertidal environments colonised by seagrass.

Table 1: Pressures and effects on seagrass as a result of human activities

Human pressure	Effect of impact on seagrass	
	Positive	Negative
Eutrophication - nutrient loading from urbanization, run off from agricultural activities and aquaculture.	May lead to increased investment in biomass and/or flowering and sexual reproduction[11].	Increased risk from disease, reduction in net growth and primary production. Increase in growth of epiphytes on subtidal seagrass and potential smothering by opportunistic algae on intertidal habitats.
Siltation - adjacent land management, shoreline erosion, dredging, dumping, mineral extraction, boating activities, fishing and aquaculture.	Nutrient inputs associated with a small increase in sedimentation may benefit seagrass growth.	Decrease in shoot density and productivity. Increase in mortality[12] due to reduced light availability for photosynthesis.
Physical disturbance of supporting sediment habitats - from dredging, trawling, bait digging, hand gathering, anchoring, construction, land reclamation.		Erosion of fine sediment, bed fragmentation and habitat loss. Plants uprooted by trawling gear and anchors. Compression of sediment and reduction in availability of oxygen to roots and rhizomes.

Table 2: Effects on seagrass due to climate change impacts. Whilst many of these are negative, there could be some positive effects too.

Climate change impact	Effect of impact on seagrass	
	Positive	Negative
Increase in seawater temperature	Senescence (deterioration) in the winter may be reduced. Increased temperatures can increase seed germination[15]. Potential for habitats to be more suitable at more northerly latitudes.	Higher temperatures in shallow waters can result in growth reduction[16,17,18], and declines in net primary production[19]. Periods of summer senescence may increase.
Sea-level rise	Potential for shift of beds inland if new habitat is created.	Coastal squeeze and loss of supporting habitat in correct tolerance range (depth, light levels, etc.). In restricted intertidal estuarine zones, populations may not be able to shift at a pace with sea-level rise.
Changes in storminess		Increase in mobilized sediment due to changes in hydrodynamics. Reduced light availability for photosynthesis. Smothering threat from burial and erosion. Potential for physical disturbance[20].
Changes to rainfall regimes	Changes in salinity are unlikely to affect distribution as both species have large salinity tolerances[21]. A decrease in salinity below ~ 22 ppt reduces wasting disease activity[22].	Higher light requirement[23] due to impact from higher sediment loads and reduced light availability. In a field experiment, negative effects were visible even at the lowest burial level (5 cm) and shortest duration (4 weeks), with increasing effects over time and burial level[24].
Ocean acidification	Raised aqueous CO_2 levels enhance seagrass survival, photosynthesis, growth, and proliferation at warm temperatures[25,26]. Seagrass growth may maintain a lower CO_2 concentration, reducing stress to calcifying organisms[27].	If calcifying organisms are stressed, there may be a reduction in epiphytic grazers, leading to seagrass stress from excess epiphytes.

A seagrass bed providing fish habitat. Ben James © SNH.

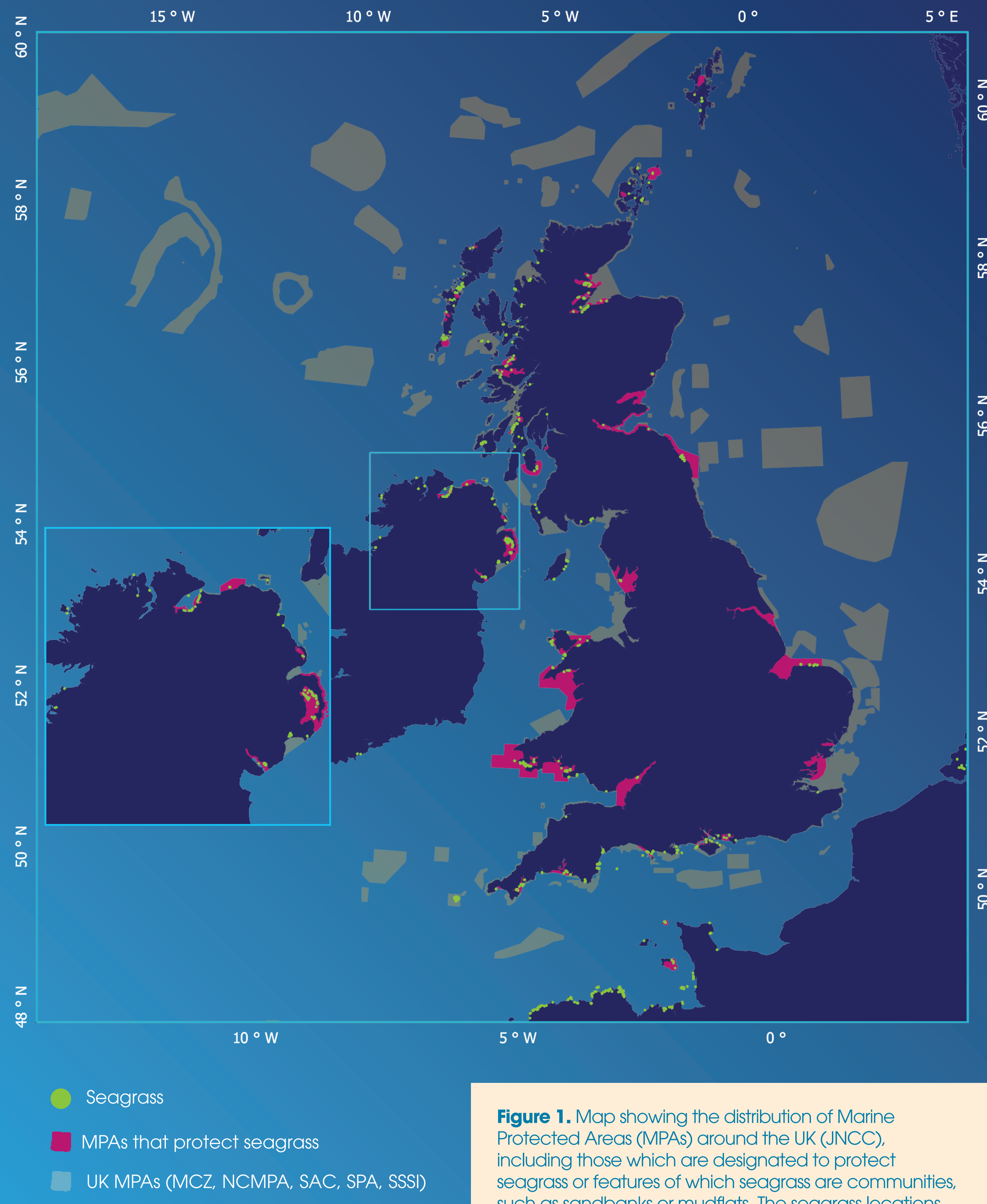
What is already being done to support management of seagrass in a changing climate?

Management measures have particularly focused on seagrass where it occurs within Marine Protected Areas (MPAs), although voluntary action through stakeholder groups has been implemented outside of sites.

To date, these measures have focused on response to human impacts rather than climate change and include:

- Closure of seagrass beds to bait digging/ hand gathering for cockles.
- Prevention of anchoring and mooring via voluntary measures and byelaws.
- Prevention of demersal fishing activities through voluntary measures, and increasingly through byelaws implemented under the revised approach to fisheries management.
- Run off management to control risk of eutrophication (e.g. diffuse water pollution plans and catchment sensitive farming).
- Access management around areas of intertidal seagrass.
- Refusal of consent for activities or development within MPAs, that would create localized changes in water temperatures, salinity, exposure etc.

A diver collecting a core sample from a seagrass bed in the Sound of Barra. Ben James © SNH



This map reflects the best available information in 2018.

Figure 1. Map showing the distribution of Marine Protected Areas (MPAs) around the UK (JNCC), including those which are designated to protect seagrass or features of which seagrass are communities, such as sandbanks or mudflats. The seagrass locations are taken from the European Marine Observation Data Network (EMODnet) and from regional administrations[28].

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

There are already a number of management measures in place to control human-induced impacts to seagrass that also support climate resilience. However, there are additional actions that could be considered to further promote resilience and adaptation. These include:

- Predictive models of seagrass distribution may be a useful tool for management and conservation efforts[29]. Predictive models have used data on the physical environment (e.g. water clarity, depth, current speed, wave exposure and sediment type and gradient) to identify site selection for transplantation[30] and to predict distribution[31]. Areas defined as suitable habitat by multiple methods can be used to conserve core populations, to serve as refugia and to help re-seed areas lost and damaged due to human activities and climate change. Combined with advice on operations in MPAs, managers could identify when low risk activities may pose a higher risk on longer time scales.
- Decision support tools can be applied that use geophysical and ecological characteristics, in a step wise process. They can be used to identify and manage situations where low risk activities, from land-based threats of nutrient and sediment runoff, could become high risk when combined with the impacts of climate change[32,33].
- Implementation of specific protective measures during coastal works e.g. prevent dredging for shellfish, vessel anchoring in beds, dredging and silt disturbing activities nearby, use silt curtains and restrict activities during sensitive periods (such as during seed dispersal in the early growing season).
- Wider considerations for Catchment Sensitive Farming, water quality plans, including controlling sedimentation, to fully protect marine features.
- Conservation action to maintain grazing species in seagrass beds, with the aim of limiting impacts of opportunistic algae that could increase with warming temperatures. This could be achieved by reducing top down predation on the grazers or culturing and adding extra grazers.

Stalked jellyfish on seagrass.
Graham Saunders © SNH

What wider management options could feasibly be considered?

- Climate change pressures, such as rising sea temperatures, mean more species need to move in order to adapt. By focusing conservation efforts on areas that could act as links to other 'shelter' habitats, such as saltmarsh, habitat corridors could be formed that allow species to move in a protected environment. Colonisation of estuarine macrofauna to seagrass has been known to be enhanced in the presence of such corridors[34]. Protecting the whole site, including its corridors, rather than individual features will ensure the wider environment is fully supported to allow for adaptation.
- Natural, long term restoration via seed or laboratory grown seedlings (after suitable habitat recreation), has been successful with *Z. marina* and other species in the USA[35,36], but has had a variable, and often low, success rate[37]. It should only be considered as a management option when there is evidence that donor populations will not be damaged, environmental conditions at new sites to replace those sites lost to climate change impacts are suitable, and reference has been made to best practice to ensure that long-term transplantation has a significant likelihood of success.
- Site management that future proofs the features in protected sites and takes into consideration the effect of management activities in adjacent marine and terrestrial ecosystems.

A recent review of the guidelines for designating SSSIs now specifically includes the requirement to future proof protected sites and their boundaries. This means that sites and their features may be designated and managed with more consideration to the impacts of climate change on supporting habitats for designated features, such as seagrass.

- Improve understanding of natural variability, through research and case studies, so this can be separated from human-induced changes in order to apply the correct management measures. This is important given it is well documented that *Zostera marina* and *noltii* undergo a high level of inter-annual change as a result of natural environmental variability.
- Updated sensitivity assessments for marine features, including seagrass, have been produced to support conservation advice delivered by agencies. These assessments could be used in combination with predicted or known climate change impacts to make expert judgement of cumulative effects of pressures. This should incorporate impacts from climate change and human sources, in order to inform effect management decisions. If these techniques can be developed to provide longer term (decadal) confidence in these assessments, they would be a valuable tool for long term marine planning to support conservation.

Practical actions to support management

Stage/ assessment	Action
Establish baseline for the feature	a) Establish the current distribution, aerial extent and cover of seagrass meadows in the UK. b) Compile any historical records with the required quality to determine any temporal change in distribution, extent and cover. c) Ascertain what, if any, management measures are already in place.
Determine vulnerability of the feature	a) Identify relevant land-based drivers that introduce nutrient or sediment loading and determine extent of current and likely future change in human pressures. b) Use direct observation and predictive modelling to project current and potential changes in the physical (water clarity, depth, wave exposure, current speed) and biological (growth, productivity, epiphytic cover) environment that will affect the feature. c) Identify the most likely effects of climate change at sites and estimate rates of change.
Determine Management options	Determine the following when taking management actions: a) What level of monitoring can be implemented to identify any change in existing meadows? b) Can improvement be made to management to reduce human impact at the site? b) Is the site at low risk to climate change and other pressures so that it can serve as a refugium? c) If the site is at high risk to climate change is there potential connectivity with better placed or adapted, adjacent seagrass beds that could act as refugia? d) Can the risk of loss be reduced by protecting meadows across a wide geographical range, covering different phenotypes and genetic make-up? Identify potential areas for growth. The effects of any actions need to be monitored and local codes of practice considered.

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