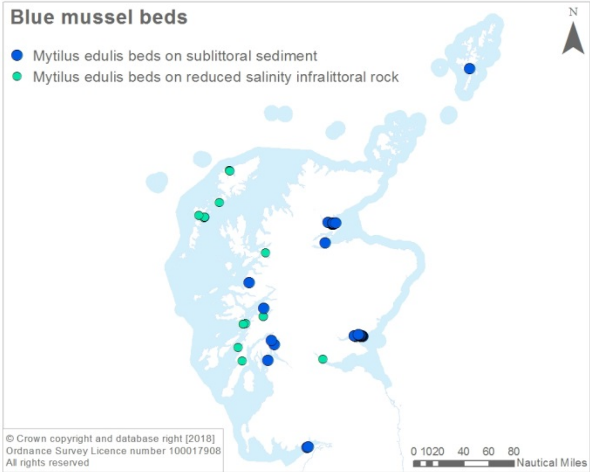
PRIORITY MARINE FEATURE (PMF) - FISHERIES MANAGEMENT REVIEW

Feature

BLUE MUSSEL BEDS - SUBTIDAL ONLY

Image	Map
 Image: SNH	

Description

Characteristics - At high densities, blue mussels (*Mytilus edulis*) form beds on subtidal sediments. The mussels attach to the substratum and to each other using tough threads (known as byssus) to create a distinctive multi-layered framework that stabilises the sediments and can extend over several hectares. Silt, organic detritus and shell debris accumulate within the bed. In this way, blue mussel beds modify sedimentary habitats and provide a habitat for a diverse community of animals and plants; living on, within, or under the bed (Buschbaum *et al*., 2009). **Intertidal blue mussel beds are not considered because there are no overlaps with towed bottom-contacting fisheries. Similarly, records of subtidal blue mussel beds on rock in reduced salinity conditions are considered inaccessible to towed gear and this component of the blue mussel beds PMF has therefore also been excluded from the review**.

Definition - Blue mussels should provide at least 20% cover of subtidal sediments over an area of at least 5 m x 5 m to qualify as a bed. This definition is informed by the OSPAR case study report for intertidal blue mussel beds on mixed and sandy sediment (OSPAR, 2010), which indicates that the ecosystem engineering effect caused by the mussels is most apparent under high densities, when substrate binding and habitat provision for other plants and animals occur. Blue mussel beds are slightly elevated (though rarely exceeding 30-50 cm thick) and support an associated community that is distinct from that inhabiting the surrounding substratum (Holt *et al*., 1998; Fariñas-Franco *et al*., 2014).

The patchy nature of most beds makes it difficult to establish their outer boundaries. A working definition used in the Wadden Sea monitoring programmes (Nehls *et al.,* 2009) proposes that small habitat patches (of at least 1-2 m diameter) may be considered part of a bed if they are within 25 m of other larger patches of habitat and if the small areas collectively cover more than 5% of the seabed. Habitat patches >25 m apart should be considered as distinct, separate beds (Fariñas-Franco *et al*., 2014).

Environmental preferences - Blue mussel beds occur in areas of moderately strong water movement (1 to 3 knots or 0.5-1.5 m/sec.) in the shallow sublittoral (down to ~10 m depth). They develop principally on mixed sediments but also on sands and muds. Blue mussels are generally tolerant to a range of temperature, salinity, oxygen concentration and water quality conditions (Holt *et al*., 1998; Fariñas-Franco *et al*., 2014).

Distribution

Scottish distribution - Subtidal blue mussel beds are restricted to a few scattered locations in lochs and firths including the Solway Firth, Firth of Clyde, Loch Creran, Loch Ailort, Dornoch Firth, Moray Firth (Moore, 2016), Firth of Tay and, Whiteness Voe in Shetland.

Estimated known Scottish extent - The largest known subtidal blue mussel beds are in the Firth of Tay (>400 ha; Bates *et al*., 2004). Several discrete beds exceeding 35 ha in size were formerly known from the Dornoch Firth (Bromham, 2010); although a 2016 survey concluded that the extent of most subtidal beds has decreased with only isolated clumps of mussels and small beds <1 hectare observed (Cook *et al*., 2016).

Wider distribution - Blue mussels are ubiquitous throughout the world's temperate waters but are most commonly encountered in exposed or moderately wave-exposed areas. Beds of the species are restricted to shallow areas with suitable substrates. In the UK, *M. edulis* is hybridised to varying degrees with two other mytilids, *M. galloprovincialis* and *M. trossulus*, and authors often refer to a "*Mytilus edulis* complex" rather than to a single species (Mathiesen *et al.,* 2016).

Status

Subtidal blue mussel beds on sediment are recognised as biogenic reefs (Holt *et al*., 1998; Maddock, 2008) under the EU Habitats Directive (European Commission, 2013). Blue mussels are a commercially targeted species and subtidal beds have been fished for hundreds of years. McKay & Fowler (1997) report multiple beds across Scotland in the 1990s, from the Solway Firth to Loch Fyne and Laxford Bay, with the majority of landings from the east coast, particularly the Dornoch Firth and the Montrose Basin.

Almost all blue mussel beds recognised as a protected feature of an MPA (e.g. as a biogenic reef or as part of a broader estuary feature) are or have been exploited historically (Holt *et al*., 1998). The approach adopted for qualifying beds within MPAs is generally to ensure that blue mussel stocks remain above a threshold that secures the long-term sustainability of the resource and that guarantees wading bird populations that rely on blue mussels as a source of food are not impacted (Moore, 2009; Stillman *et al*., 2010).

The Dornoch Firth was once the largest mussel producer in the UK with two vessels operating and landings of over 2500 tonnes in 1991 (McKay & Fowler, 1997). Mussel scalps were dredged to thin out the beds and mussels were also moved around within the firth to enhance growing rates. Cook *et al.* (2016) report a substantial decline in subtidal mussel beds in the Dornoch Firth with scattered, small (<1 ha) beds likely to be the remains of larger beds present in the 1990s and later reported by BMT Cordah (2004) and Bromham (2012). In 2016/17 the mussel fishery in the Dornoch Firth was 'rested' on the basis of professional advice to allow the stock to recover to former levels prior to any fisheries activity restarting (The Highland Council, 2017).

The scientific advice provided to the Highland Council (Cook *et al*., 2016) also highlighted the presence of a horse mussel bed and fragile sponge communities within the Dornoch Firth, noting that these additional habitats of nature conservation importance should be avoided if blue mussel dredging were to recommence in the future.

Sensitivity (including recovery)

[Key sources: Fisheries Management Guidance]

Blue mussel beds are sensitive to habitat structure changes. Physical loss of habitat and removal of substratum are particularly damaging pressures, while the sensitivity of blue mussel beds to non-indigenous species is dependent on the species assessed (e.g. the slipper limpet *Crepidula fornicata* has the potential to out-compete blue mussels) (Mainwaring *et al*., 2014). Mass mortalities of blue mussels can also occur due to hypoxia (Fariñas-Franco *et al*., 2014).

Blue mussel beds may be vulnerable to future climate impacts associated with sea level rise, increasing water temperatures and changes in seawater chemistry (see OARUG, 2009). Blue mussels exhibit reduced growth and altered material properties when grown under future projected ocean acidification conditions (Fitzer *et al*., 2014). The blue mussel shells harden and the reduction in elasticity makes them more prone to fracture in stormy conditions and vulnerable to predation (Fitzer *et al*., 2014). Ocean acidification may also weaken the byssus threads that attach the mussels to the seabed or shoreline increasing the likelihood of detachment (O'Donnell *et al*., 2013; Zhao *et al*., 2017). Economic losses associated with ocean acidification could be substantial (Mangi *et al*., 2018).

Activities such as towed bottom-contacting fishing (targeted or accidental), anchoring, pollution and potential development can all impact subtidal blue mussel beds. Direct removal of the mussels through dredging and trawling activities results in loss of biogenic reef habitat and species richness of benthic invertebrate communities (Ragnarsson & Raffaelli, 1999; Dolmer *et al*., 2001). Dredging may also increase the vulnerability of mussel beds to storm damage resulting in a reduction in extent or complete loss (Ens, 2006). Some degree of fishing does not necessarily have negative effects on mussel stocks and can result in increases in biomass and expansion of the beds resulting from the opening of settlement spaces and a reduction in inter-specific competition (Laursen *et al*., 2010). It is therefore possible for mussel density and the extent of fished beds to increase. Nevertheless, most studies suggest that overfishing is the driving force in the declines recorded in mussel beds (e.g. in the Wadden Sea and The Wash - Dolmer *et al*., 1999; Jessop, 2017). Overall, more transient populations are found on mobile sediments and in dynamic environments such as estuaries (Fariñas-Franco *et al*., 2014).

Over-exploitation of subtidal beds may reduce subsequent recruitment, although this relationship is poorly understood. Blue mussel populations are considered to have a strong ability to recover from environmental disturbance but annual recruitment cannot always be guaranteed (i.e. it is episodic). Recovery potential is therefore thought to be variable (Mainwaring *et al*., 2014; Tillin & Mainwaring, 2016).

Connectivity

Between subtidal blue mussel beds - Spawning and successful settlement by blue mussels is sporadic and unpredictable. Larvae stay in the plankton for between 20 days and two months depending on water temperature (Bayne, 1976) and can delay metamorphosis for 6 months in unfavourable conditions (Lane *et al*., 1985). This long pelagic larval dispersal phase may result in high potential connectivity. Intertidal mussel beds are more common than subtidal beds and sometimes continue into the subtidal where the substrate is suitable. It is likely that subtidal beds rely on a supply of larvae from intertidal beds in places and vice versa. In this way, intertidal beds may act as stepping stone populations to maintain connectivity of subtidal populations. Further research is required to better understand connectivity of blue mussel beds.

With other PMFs - Blue mussel beds have been reported from the same location as *horse mussel beds* in the Dornoch Firth (The Highland Council, 2017) although the latter PMF is more commonly encountered in deeper waters. Blue mussel beds in the intertidal zone can occur within *seagrass beds* and on *intertidal mudflats,* helping to provide support and structure for the sediments.

Subtidal blue mussel beds on sediment are believed to compete for space with reefs of the honeycomb worm *Sabellaria alveolata* in the outer part of the Solway Firth (Axelsson *et al*., 2006). *S. alveolata* is not a PMF in Scottish waters because it reaches its northerly limit in this MPA, but is a habitat of nature conservation importance that, like blue mussels, forms biogenic reefs recognised under the EU Habitats Directive.

Ecosystem services	
• Biomass production • Larval/gamete supply (supporting connectivity) • Nutrient cycling • Formation of habitat for other species (supporting biodiversity) • Formation of physical barrier • Resilience to INNS & disease • Waste breakdown & detoxification of water and sediments	• Coastal protection • Carbon storage & climate regulation • Sediment stabilisation • Fish and shellfish stocks • Ornamental materials (commercial & personal) • Genetic resources • Socially valued places/seascapes • Watching/studying nature

Existing Marine Protected Areas

Blue mussel beds on subtidal sediments are a protected feature of 4 MPAs: Firth of Tay and Eden Estuary; Dornoch Firth and Morrich More; Solway Firth; and, Loch Creran.

Existing and proposed fisheries measures providing PMF protection

Details of existing fisheries measures within the Loch Creran MPA are available on Marine Scotland's web pages (http://www.gov.scot/Topics/marine/marine-environment/mpanetwork/MPAMGT/protectedareasmgt).

New fisheries management measures that will provide PMF protection in the Firth of Tay and Eden Estuary MPA and the Dornoch Firth and Morrich More MPA will be consulted upon later in 2018 (see - http://www.gov.scot/Topics/marine/marine-environment/mpanetwork/inshorempas/Management).

Proposed measures in the Dornoch Firth are expected to derogate the Tain mussel fishery from wider mechanical dredge prohibitions and enable future fishing subject to satisfying a Habitats Regulation Appraisal for the Special Area of Conservation.

The cockle fishery within the Solway Firth MPA is currently closed and there are significant spatial and technical restrictions in place for the shrimp fishery.

Subtidal blue mussel beds are afforded protection by virtue of fisheries measures associated with other designated features in the Sound of Arisaig MPA and the Moray Firth MPA.

Examples of PMFs that have no or partial coverage by fisheries measures

- Firth of Clyde - subtidal mussel beds have been recorded on sediments around an old oil terminal jetty in Loch Long and off a jetty to the south of Inverkip marina in Largs.
- Solway Firth - subtidal blue mussel bed records have been tagged as 'unmanaged' because permanent prohibitions on bottom-contacting fishing gear are not in place.
- Shetland - a subtidal bed in Whiteness Voe is located within one of the Shetland Shellfish Management Organisation areas (SSMO - https://www.ssmo.co.uk/maps) which is closed to dredging.

Assessment against National Marine Plan General Policy 9:
Development and use of the marine environment must not result in significant impact on the national status of Priority Marine Features.

Blue mussels are ecosystem engineers and blue mussel beds enhance biodiversity of sedimentary coastal systems by increasing habitat heterogeneity (Buschbaum *et al*., 2009). They provide a complex structure for organisms to attach in otherwise species-poor areas of mud or sand. Mussel beds are also important for nutrient cycling and act as a top down control on plankton abundance. While intertidal mussel beds are common, subtidal beds are rare; known only from a few inlets in Scotland (Howson *et al*., 2012) and substantial declines have been recorded (Cook *et al*., 2016). Therefore any activities that lead to the loss of entire beds or damage beds to the extent that function or provision of ecosystem services cannot be maintained should be considered a significant impact on national status.

Existing licensing and consenting processes will continue to consider the potential for significant impacts on the national status of development proposals on subtidal blue mussel beds. The following assessment relates to fishing using towed bottom-contacting gear only but is consistent with the approach taken for assessing proposed developments. Please refer to the *consultation overview* for further details.

In a fisheries context, additional measures to protect subtidal blue mussel beds from pressures associated with towed bottom-contacting gears are recommended in the **Dornoch Firth** and **Solway Firth**. The recommendations for subtidal blue mussel beds need to be considered alongside the recommendations for the other 10 PMFs considered as part of this review. The areas identified provide a starting point for discussions regarding future fisheries management. These discussions will be led by Marine Scotland.

Subtidal beds within the Dornoch Firth are tagged as 'managed' on the map provided because proposed measures would prohibit bottom-contacting fishing gear. However, a derogation is proposed for the Tain mussel dredge fishery to continue on its current basis providing that it satisfies a Habitats Regulations Appraisal.

Fisheries management should aim to limit levels of exploitation to a point which allows beds to persist over the long-term and maintain associated biodiversity. Where historic exploitation has reduced the extent of beds, management of effort may be necessary in order to allow recovery. In light of the declines observed in both the extent and abundance of subtidal blue mussel beds across the firth, it is recommended that the HRA be informed by further and ongoing assessment of the current status of the blue mussel beds (which should encompass parameters such as area covered, biomass, and adult mussel abundance - see Fariñas-Franco *et al*., 2014 for further details). Formalising spatial restrictions to protect a recently mapped horse mussel bed and associated fragile sponge communities in the outer part of the estuary should also be considered. The responsible approach taken by Highland Council and Tain Community Council in resting the blue mussel fishery until 2005 levels of stocks are reached again; stipulating the need for a future stock assessment survey that can inform HRA; and, in identifying the horse mussel bed as a sensitive area to be avoided if the fishery re-starts (The Highland Council, 2017) is recognised and welcomed.

It is currently unclear whether the declines observed in the Dornoch Firth blue mussel beds reflect a broader picture across the North Sea (OSPAR, 2010). Surveys of rocky shores around the Scottish coastline over the last 20 years have seen a marked decline in blue mussels (Burrows *et al*., 2016) with comparable observations from more localised studies (e.g. Moore & Howson, 2014; Wallace, 2016). Declines in mussel species have also been charted on the east coast of the USA (Sorte *et al*., 2016) and on the Pacific west coast of North America, where the changes were associated with a decadal decline in nearshore pH levels (Wootton *et al*., 2008). Blue mussel populations have been known to fluctuate in abundance historically over similar timescales so it is inappropriate to infer a long-term climatic effect on Scottish mussel populations but due consideration should be given to the wider status of blue mussels as part of the Dornoch Firth HRA process.

In the Solway Firth, very high densities of blue mussels were recorded (10,500 individuals per 0.1 m^2) in Silloth Channel in 2004 (Axelsson *et al*., 2006). High densities of blue mussels were recorded at an additional site during the 2004 survey but this was assigned to a honeycomb worm habitat due to the high abundance of *Sabellaria alveolata* (Axelsson *et al*., 2006). Horse mussel beds have also been reported from subtidal scar grounds in the Solway Firth (Cutts & Hemmingway, 1996; Allen *et al*., 1999 - records not in the database), although, the authors suggest that these beds may be short lived due to fishing pressures (Allen *et al*., 1999). Both blue mussels and horse mussels have been identified in previous studies within the Solway Firth (Williams *et al*., 1965; Perkins, 1968; 1986). The mussel scars in the Solway Firth may be quite ephemeral, with newly formed beds appearing each year following spat settlement events only to be washed away by storms, suggesting that their exact location and extent will continue to be highly variable (Fariñas-Franco *et al*., 2014).

Marine Scotland consider the existing spatial and technical restrictions in place for the only two fisheries of note (shrimp and cockle fisheries) sufficient to protect the seabed habitats within the MPA but it is currently unclear how these fishing activities relate to the blue mussel beds. There are records of opportunistic landings of mussels from subtidal beds in the Solway by brown shrimp dredgers (see McKay & Fowler, 1997).

Knowledge gaps and other records

Knowledge gaps - A 2015 record from a dive survey off a jetty in Largs marina requires further investigation as this is described as "*possible edible mussels on the sea bed, unclear whether shells are living or dead*". A record from 2012 describes a blue mussel bed within a kelp park around an old oil terminal jetty in Loch Long, however, the extent and density of this bed is currently unknown. These two discrete locations are displayed as a single **Inverkip and Loch Long** knowledge gap on the map provided. Further information is also required on the current status of the bed recorded in **Whiteness Voe** in Shetland in 1994.

Other records - This feature is likely to be under-recorded and there are knowledge gaps regarding the distribution of habitat suitable for subtidal blue mussel bed development. It is possible that beds exist within formerly exploited areas such as the Firth of Forth.

There are 19 records of subtidal blue mussel beds on reduced salinity rock of which only one is considered potentially accessible to towed bottom-contacting fishing gear. This record is in the Dornoch Firth MPA. These records have been displayed on the map provided but have not otherwise been considered in this review.

Data confidence

Available records span 1989 to 2015. Surveys vary in their original aims from Seasearch (carried out by volunteer divers); to studies undertaken to inform development proposals and dedicated MPA-related nature conservation assessments (e.g. the 2004 SNH survey in the Solway Firth).

Blue mussel bed stock assessment data collected in the Dornoch Firth in 2016 were also considered as part of this assessment (Cook *et al*., 2016; The Highland Council, 2017). The work, which was undertaken by experienced marine biologists, explored earlier intertidal and subtidal mussel bed records using drop-down video, diver-based density estimates and shore-based, structured walk methodologies.

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Areas where fisheries management should be considered to avoid a significant impact on the national status of the PMF