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Marine Information Network
Information on the species and habitats around the coasts and sea of the British Isles

Mytilus edulis and barnacles on very exposed eulittoral rock

MarLIN – Marine Life Information Network
Marine Evidence–based Sensitivity Assessment (MarESA) Review

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Close view of *Mytilus* and dense barnacles covering rock surface.
Photographer: Anon.
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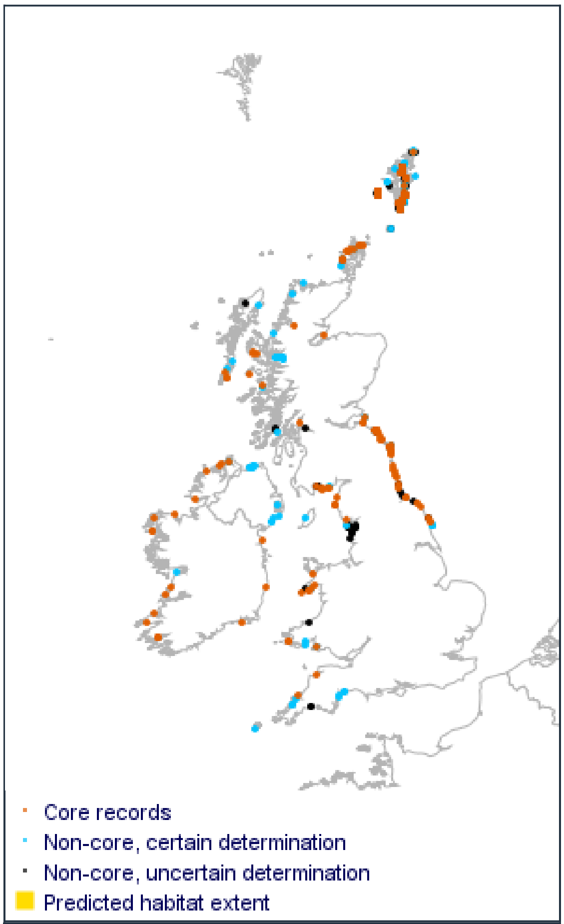

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Dr Heidi Tillin & Dr Harvey Tyler-Walters **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	A1.111	*Mytilus edulis* and barnacles on very exposed eulittoral rock
JNCC 2015	LR.HLR.MusB.MytB	*Mytilus edulis* and barnacles on very exposed eulittoral rock
JNCC 2004	LR.HLR.MusB.MytB	*Mytilus edulis* and barnacles on very exposed eulittoral rock
1997 Biotope	LR.ELR.MB.MytB	*Mytilus edulis* and barnacles on very exposed eulittoral rock

Description

The eulittoral zone, particularly mid and lower shore zones, of very exposed rocky shores are typically characterized by patches of small mussels *Mytilus edulis* interspersed with patches of barnacles *Semibalanus balanoides*. Amongst the mussels small red algae including *Ceramium shuttleworthianum*, *Corallina officinalis*, *Mastocarpus stellatus* and *Aglaothamnion* spp. can be found. Two red algae in particular, *Porphyra umbilicalis* and *Palmaria palmata*, are commonly found on the *Mytilus* itself and can form luxuriant growths. The abundance of the red algae generally increases down the shore and in the lower eulittoral they may form a distinct zone in which mussels or barnacles are scarce (MLR.R, ELR.Him or ELR.Coff). Where *Mytilus* occurs on steep rock, red algae are scarce, and restricted to the lower levels. The dog whelk *Nucella lapillus* and a few littorinid molluscs occur where cracks and crevices provide a refuge in the rock. Fucoids are generally absent, although some *Fucus vesiculosus f. linearis* may occur where the shore slopes more gently. ELR.MytB is generally found above a zone of either mixed turf-forming red algae (MLR.R), *Himanthalia elongata* (ELR.Him) or above the sublittoral fringe kelp *Alaria esculenta* (EIR.Ala). Above ELR.MytB there may be a *Porphyra* zone (LR.Ver.Por), a *Verrucaria maura* and sparse barnacle zone (LR.Ver.B) or a denser barnacle and limpet zone (ELR.BPat), often with *Porphyra*. In addition, patches of *Lichina pygmaea* with barnacles (ELR.BPat.Lic) may also occur above this biotope, particularly on southern shores. This biotope also occurs on steep moderately exposed shores which experience increased wave crash. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

Depth range

-

Additional information

None

Listed By

- none -

Further information sources

Search on:

G G JNCC

Habitat review

Ecology

Ecological and functional relationships

Rocky shores demonstrate a complex array of ecological relationships, between space occupying species and their predators, and macroalgae and their grazers. The complex of relationships results from variable competitive hierarchies dependant on stochastic events (e.g. larval recruitment, physical disturbance and weather) affecting species abundance and density and deterministic processes such as succession. The information that follows has been derived from survey data (Connor *et al*., 1997; JNCC, 1999) and more detailed studies by Hawkins & Hartnoll (1983), Suchanek (1985), Tsuchiya & Nishihira (1985 & 1986), Seed & Suchanek (1992), Hawkins *et al.* (1992), Holt *et al.* (1998), and Raffaelli & Hawkins (1999). Please note that recent evidence suggests that the *Mytilus edulis* communities studied by Suchanek 1985 and Tsuchiya & Nishihira (1985 & 1986) were probably *Mytilus trossulus* and *Mytilus galloprovincialis* respectively (Seed, 1992), although their community ecology is probably similar.

- *Mytilus edulis* and *Semibalanus balanoides* are the dominant space occupying species, competing for available space, Their relative abundance is probably dependant on variation in recruitment intensity and physical disturbance, both species becoming more vulnerable to wave disturbance with age and large size. *Mytilus edulis* can colonize free substratum but recruitment may be enhanced by the presence of barnacles (Seed & Suchanek, 1992). *Mytilus edulis* is potentially competitively dominant and capable of overgrowing the barnacles.
- *Mytilus edulis* are active suspension feeders on bacteria, phytoplankton, detritus, and dissolved organic matter (DOM), while barnacles are active and passive suspension feeders on zooplankton and detritus.
- The presence of other suspension feeders is probably dependant on the availability of suitable habitats, e.g. interstitial or crevice dwelling micro-molluscs such as *Lasaea adansoni* and *Turtonia minuta* or epizoic tubeworms (e.g. *Spirobranchus* spp.) and the occasional epiphytic hydroid (e.g. *Dynamena pumila*).
- The macroalgae (e.g. *Mastocarpus stellatus*, *Corallina officinalis*, *Porphyra umbilicalis* and *Ceramium* spp.) provide primary production to the community and the surrounding ecosystem directly to grazers, or indirectly in the form of abraded algal particulates and detritus, algal spores, algal exudates and dissolved organic matter.
- On wave exposed shores, grazers such as limpets and gastropods control macroalgal growth. Limpets are abundant, grazing macroalgal sporelings, benthic microalgae, fucoid fronds and ephemeral seaweeds. Limpet grazing is inhibited by high abundance of older barnacles. Towards the bottom of the shore at the lower limit of the biotope the damper conditions favour macroalgal growth and macroalgal abundance and diversity increases (see Hawkins & Hartnoll, 1983; Hawkins *et al*., 1992; Raffaelli & Hawkins, 1999). *Littorina saxatilis* and *Littorina neglecta* feed on benthic microalgae and sporelings but may switch to fucoids when available (Hawkins & Hartnoll, 1983).
- Mesoherbivores such as amphipods and isopods (e.g. *Hyale prevosti*, *Orchestia gammarellus*, *Idotea granulosa*) feeding of ephermeral algae, epiphytic algae, old and dying macroalgae and affect dispersal and recruitment of macroalgal propagules (see Brawley, 1992b).
- Patches of mussels support deposit feeders or detritivores such as polychaetes (e.g. *Cirratulus cirratus* and terebellids) and scavengers feeding on dead mussels within the matrix, e.g. flatworms, small crabs and polychaetes (Kautsky, 1981; Tsuchiya & Nishihira,

1985,1986), while other polychaetes (e.g. scale worms), small crabs and nemerteans are predatory within the matrix.

Predation is the single most important source of mortality in *Mytilus edulis* populations (Seed & Suchanek, 1992; Holt *et al.*, 1998). Many predators target specific sizes of mussels and, therefore influence population size structure. For example, *Carcinus maenas* was unable to consume mussels of ca. 70mm in length and mussels >45mm long were probably safe from attack (Davies *et al.*, 1980; Holt *et al.*, 1998). The lower limit of intertidal mussel populations may be limited by predation by starfish (e.g. *Asterias rubens*), *Carcinus maenas* and the dogwhelk *Nucella lapillus*.

- Dogwhelks prey on barnacles and mussels, large dogwhelks preferring larger prey (see *MarLIN* review). The relative importance of dogwhelk predation reduces with increasing wave exposure, except of shores with an adequate supply of refuges (crevices, cracks or gullies) from which dogwhelks can forage (Holt *et al.*, 1998; Raffaelli & Hawkins, 1999).
- Flatfish such as *Platichthys flesus* (plaice), *Pleuronectes platessa* (flounder) and *Limanda limanda* (dab), where present, feed on mussels.
- Birds are important predators of mussels, and oystercatchers, herring gulls, eider ducks and knot have been reported to be major sources of *Mytilus edulis* mortality. Although, probably of greatest importance in sedimentary habitats, bird predation, especially by oystercatchers, probably significantly affects the population dynamics of intertidal mussel beds. Oystercatchers and gulls also prey on limpets, while other species of birds probably consume small gastropods, small crustacea (e.g. amphipods and isopods) and crabs.

Seasonal and longer term change

Barnacle dominated rocky shores demonstrate dynamic temporal changes, mediated by relatively random events such as recruitment intensity, and the abundance of grazers and predators. The dynamic changes were best studied in semi-exposed coasts of Isle of Man (Hawkins & Hartnoll, 1983; Hawkins *et al.*, 1992; Raffaelli & Hawkins, 1999). In summary, local reductions in limpet abundance result in escapes of fucoids. Clumps of fucoids discourage barnacles settlement due to sweeping of their fronds but encourage recruitment of limpets and dogwhelks which aggregate under their fronds. Fucoids are lost due to wave action, ageing and loss of old barnacles to which they are attached. Fucoids cannot recruit to the available space due to aggregations of limpet. The loss of shelter provided by the fucoids causes limpet and dogwhelks to disperse allowing barnacles to settle. In dense older stands of barnacles limpet graze poorly, allowing escapes of fucoids (see Raffaelli & Hawkins, 1999, figure 4.5). The relative importance of limpet or other gastropod grazing and dogwhelk predation varies with location and shore exposure but is still of importance on exposed shores. The dynamic process favours fucoids on sheltered shores presumably because the macroalgae are able to grow and recruit faster than on exposed shores, whereas wave exposed coasts favour dense barnacles and mussels.

The condition of *Mytilus edulis* varies with season and reproductive cycle. Spawning is protracted in many populations, with a peak of spawning in spring and summer. A partial spawning in spring is followed by rapid gametogenesis, gonads ripening by early summer, resulting in a less intensive secondary spawning in summer to late August or September. Mantle tissues store nutrient reserves between August and October, ready for gametogenesis in winter when food is scarce. The secondary spawning, is opportunistic, depending on favourable environmental conditions and food availability. Gametogenesis and spawning varies with geographic location, e.g. southern populations often spawn before more northern populations (Seed & Suchanek, 1992).

Winter storms can result in gaps forming in the mussel bed and barnacle cover, especially where the barnacles or mussels are fouled by macroalgae or epifauna, due to wave action and drag, or direct impact by wave driven debris, e.g. logs (Seed & Suchanek, 1992).

Seasonal changes in weather and recruitment will result in variation in the relative abundance of mussel or barnacles, their predators and grazers. For example, hot summers may reduce predation by dogwhelks, grazing by limpets or the upper limit of mussels. Similarly recruitment in *Chthamalus* species is favoured in warm years while colder years favour *Semibalanus balanoides* (Southward *et al*., 1995; Raffaelli & Hawkins, 1999). Seed (1996) reported that the invertebrate communities within mussel patches exhibit significant temporal and small-scale spatial variations in diversity and abundance, that probably reflect the stochastic nature of larval recruitment and settlement. The abundance and cover of macroalgae varies with season, fronds dying back or being removed by winter storms to grow back in early spring. Dogwhelk predation pressure varies with season, feeding reduced in winter but active in spring and summer. The barnacle population can be depleted by the foraging activity of the dogwhelk *Nucella lapillus* from spring to early winter and replenished by settlement of *Semibalanus balanoides* in the spring and *Chthamalus* species in the summer and autumn. Crab and fish tend to move to deeper water in the winter months, so that predation is probably reduced in winter.

Habitat structure and complexity

The *Mytilus edulis* patches and barnacles dominated substratum denote areas of different habitat complexity and species richness. Patches (or 'islands') of mussels may support a diverse community (see Suchanek,1985; Tsuchiya & Nishihira, 1985, 1986) whereas the interstices of barnacles provide shelter for small species (see Barnes, 2000 for review). Please note that recent evidence suggests that the *Mytilus edulis* communities studied by Suchanek 1985 and Tsuchiya & Nishihira (1985 & 1986) were probably *Mytilus trossulus* and *Mytilus galloprovincialis* respectively (Seed, 1992), although their community ecology is probably similar. The habitat complexity and species diversity of the shore depends on the relative abundance of mussel and barnacles, the presence of macroalgae and crevices.

Mussel patches ('islands')

- The gaps between interconnected mussels form numerous interstices for a variety of organisms. The interstices between the mussels provide refuge from predation, and provide a humid environment protected from wave action, desiccation, and extremes of temperature. In the intertidal, the species richness and diversity of mussel patches increases with the age and size of the patch (Suchanek, 1985; Tsuchiya & Nishihira, 1985,1986; Seed & Suchanek, 1992). The mussel matrix may support sea cucumbers, anemones, boring clionid sponges, ascidians, crabs, nemerteans, errant polychaetes and flatworms (Suchanek, 1985; Tsuchiya & Nishihira, 1985,1986).
- Mussel faeces and pseudo-faeces, together with silt, build up organic biodeposits under the beds. The biodeposits attract infauna such as sediment dwelling sipunculids, polychaetes and ophiuroids (Suchanek, 1978; Seed & Suchanek, 1992, Tsuchiya & Nishihira, 1985,1986). However, flushing by wave action prevents the build up of the thick layer of biodeposits found in *Mytilus* reefs.
- Epizoans may use the mussels shells themselves as substrata. However, *Mytilus edulis* can use its prehensile foot to clean fouling organisms from its shell (Theisen, 1972). Therefore, the epizoan flora and fauna is probably less developed or diverse than found in beds of other mussel species. However, epifauna include barnacles (e.g. *Austrominius modestus*) and tubeworms (e.g. *Spirobranchus* species)

- Mobile epifauna include isopods, chitons (e.g. *Lepidochitona cinerea*) and gastropods such as littorinids (e.g. *Littorina littorea*) and topshells (e.g. *Gibbula* species), which obtain refuge from predators, especially birds, within the mussel matrix, emerging at high tide to forage (Suchanek, 1985; Seed & Suchanek, 1992).
- The mussels provide a substratum for the attachment of macroalgae such as foliose and filamentous algae e.g. *Ceramium* species, *Palmaria palmata* and *Porphyra umbilicalis*. The abundance of red algae increases down the shore, with *Corallina officinalis* and *Mastocarpus stellatus* growing on the substratum. Where macroalgae are present the community also supports small crustaceans such as gammarid amphipods and isopods (e.g. *Idotea granulosa*) (Seed & Suchanek, 1992, Tsuchiya & Nishihira, 1985,1986). Ephemeral algae such as *Ulva* spp. And *Ulva lactuca* may also grow on the mussels themselves.

Barnacle dominated substratum

- Barnacles form a tightly packed covering over the substratum excluding other species. Dead barnacles leave gaps in the covering that can be exploited by small invertebrates.
- Small interstitial species occupy relatively stable microclimates in-between barnacles or in dead barnacles shells, including the small littorinids *Littorina neglecta* and *Littorina saxatilis*, the bivalve *Lasaea adansoni*, intertidal mites, amphipods and isopods.
- Wave sheltered large crevices and gullies provide refuges for dogwhelks and littorinids, while crevices provide refuges for predatory nemerteans and polychaetes (e.g. *Eulalia viridis*).

Productivity

The absence, or low abundance, of macroalgae limits primary production in this biotope to microalgae growing on rock surfaces so that primary productivity in the ELR.MytB biotope is probably not as high as some other rocky shore biotopes. *Mytilus* communities are highly productive secondary producers (Seed & Suchanek, 1992; Holt *et al*., 1998). Low shore mussels were reported to grow 3.5-4cm in 30 weeks and up to 6-8cm in length in 2 years under favourable conditions, although high shore mussels may only reach 2-3cm in length after 15-20 years (Seed, 1976). However, mussel productivity in this biotope is probably reduced due to their patchy nature. The *Mytilus edulis* clumps and dense barnacles probably also provide secondary productivity in the form of tissue, faeces and pseudofaeces (Seed & Suchanek, 1992; Holt *et al*., 1998). Rocky shores can make a contribution to the food of many marine species through the production of planktonic larvae and propagules which contribute to pelagic food chains.

Recruitment processes

Most species present in the biotope possess a planktonic stage (gamete, spore or larvae) which float in the plankton before settling and metamorphosing into the adult form. This strategy allows species to rapidly colonize new areas that become available such as in the gaps often created by storms. Thus, for organisms such as those present in this biotope, recruitment from the pelagic phase is important in governing the density of populations on the shore (Little & Kitching, 1996). Both the demographic structure of populations and the composition of assemblages may be profoundly affected by variation in recruitment rates.

- Barnacle settlement and recruitment can be highly variable because it is dependent on a suite of environmental and biological factors, such as wind direction and success depends on settlement being followed by a period of favourable weather (see *Semibalanus* balanoides review for discussion). Long-term surveys have produced clear evidence of barnacle populations responding to climatic changes. During warm periods *Chthamalus* spp. Predominate, whilst *Semibalanus balanoides* does better during colder spells (Hawkins *et al*., 1994; Southward *et al*., 1995). Release of *Semibalanus balanoides* larvae takes place between February and April with peak settlement between April and June. Release of larvae of *Chthamalus montagui* takes place later in the year, between May and August. However, settlement intensity is variable, subsequent recruitment is inhibited by the sweeping action of macroalgal canopies (e.g. fucoids) or the bulldozing of limpets and other gastropods (see *MarLIN* review for details).

- *Mytilus edulis* recruitment is dependant on larval supply and settlement, together with larval and post-settlement mortality. Gametogenesis and spawning varies with geographic location, e.g. southern populations often spawn before more northern populations (Seed & Suchanek, 1992). Spawning is protracted in many populations, with a peak of spawning in spring and summer and settlement approximately 1 month later. JØrgensen (1981) estimated that larvae suffered a daily mortality of 13% in the Isefjord, Denmark. Lutz & Kennish (1992) suggested that larval mortality was approximately 99%. Larval mortality is probably due to adverse environmental conditions, especially temperature, inadequate food supply (fluctuations in phytoplankton populations), inhalation by suspension feeding adult mytilids, difficulty in finding suitable substrata and predation (Lutz & Kennish, 1992). Widdows (1991) suggested that any environmental factor that increased development time, or the time between fertilization and settlement would increase larval mortality.
- Recruitment in many *Mytilus* sp. populations is sporadic, with unpredictable pulses of recruitment (Seed & Suchanek, 1992). *Mytilus* sp. is highly gregarious and final settlement often occurs around or in-between individual mussels of established populations. Pedi-veliger larvae may settle first on filamentous substrata, such as hydroids and algae, so that beds of filamentous algae (e.g. *Corallina* spp., *Ceramium* spp. And *Mastocarpus stellatus*) may provide a pool of young mussels that can subsequently colonize the bed. Competition with surrounding adults may suppress growth of the young mussels settling within the mussel bed, due to competition for food and space, until larger mussels are lost (Seed & Suchanek, 1992). However, young mussels tend to divert resources to rapid growth rather than reproduction. The presence of macroalgae in disturbance gaps in *Mytilus califorianus* populations, where grazers were excluded, inhibited recovery by the mussels. In New England, U.S.A, prior barnacle cover was found to enhance recovery by *Mytilus edulis* (Seed & Suchanek, 1992). Persistent mussels beds can be maintained by relatively low levels of recruitment e.g. McGrorty *et al*., (1990) reported that adult populations were largely unaffected by large variations in spatfall between 1976-1983 in the Exe estuary.
- The *Mytilus edulis* bed may act as a refuge for larvae or juveniles, however, the intense suspension feeding activity of the mussels is likely to consume large numbers of pelagic larvae. Commito (1987) suggested that species that reproduce with cocoons, brood their young or disperse as juveniles will be favoured (see gastropods below).
- Gastropods exhibit a variety of reproductive life cycles. The common limpet *Patella vulgata*, the topshell *Steromphala umbilicalis*, and *Littorina littorea* have pelagic larvae with a high dispersal potential, although recruitment and settlement is probably variable. Recruitment of *Patella vulgata* fluctuates from year to year and from place to place. Fertilization is external and the larvae is pelagic for up to two weeks before settling on rock at a shell length of about 0.2mm. Winter breeding occurs only in southern England, in the north of Scotland it breeds in August and in north-east England in September. However, *Littorina obtusata* lays its eggs on the fronds of fucoids form which hatch crawl-away miniature adults. Similarly, the dogwhelk *Nucella lapillus* lays egg capsules on hard

substrata in damp places on the shore, from which crawl-aways emerge. Therefore, their dispersal potential is limited but probably designed to colonize an abundant food source. In addition, most gastropods are relatively mobile, so that a large proportion of recruitment of available niches within a mussel bed would involve migration. *Nucella lapillus* is an exception, as they generally do not move far, averaging 100mm /tidal cycle, or between 30cm or 10m per year when in the vicinity of an abundant food source (see *MarLIN* reviews for details; Fish & Fish, 1996).

- The propagules of most macroalgae tend to settle near the parent plant (Schiel & Foster, 1986; Norton, 1992; Holt *et al.*, 1997). For example, the propagules of fucales are large and sink readily and red algal spores and gametes and immotile. Norton (1992) noted that algal spore dispersal is probably determined by currents and turbulent deposition (zygotes or spores being thrown against the substratum). For example, spores of *Ulva* spp. Have been reported to travel 35km, *Phycodrys rubens* 5km and *Sargassum muticum* up to 1km, although most *Sargassum muticum* spores settle within 2m. The reach of the furthest propagule and useful dispersal range are not the same thing and recruitment usually occurs on a local scale, typically within 10m of the parent plant (Norton, 1992). Vadas *et al.* (1992) noted that post-settlement mortality of algal propagules and early germlings was high, primarily due to grazing, canopy and turf effects, water movement and desiccation (in the intertidal) and concluded that algal recruitment was highly variable and sporadic. However, macroalgae are highly fecund and widespread in the coastal zone so that recruitment may be still be rapid, especially in the rapid growing ephemeral species such as *Ulva* spp. And *Ulva lactuca*, which reproduce throughout the year with a peak in summer. Similarly, *Ceramium* species produce reproductive propagules throughout the year, while *Mastocarpus stellatus*produce propagules form February to December, and exhibit distinct reproductive papillae in summer (Dixon & Irvine, 1977; Burrows, 1991; Maggs & Hommersand, 1993).
- Many species of mobile epifauna, such as polychaetes have long lived pelagic larvae and/or are highly motile as adults. Gammarid amphipods brood their embryos and offspring but are highly mobile as adults and probably capable of colonizing new habitats from the surrounding area (e.g. see *Hyale prevosti* review).

Time for community to reach maturity

Bennell (1981) observed that barnacles that were removed when the surface rock was scraped off in a barge accident at Amlwch, North Wales returned to pre-accident levels within 3 years. However, barnacle recruitment can be very variable because it is dependent on a suite of environmental and biological factors, such as wind direction, so populations may take longer to recruit to suitable areas. Recolonization of *Patella vulgata* on rocky shores is rapid as seen by the appearance of limpet spat 6 months after the *Torrey Canyon* oil spill reaching peak numbers 4-5 years after the spill (Southward & Southward, 1978). Larval supply and settlement in *Mytilus edulis* could potentially occur annually, however, settlement is sporadic with unpredictable pulses of recruitment (Lutz & Kennish, 1992; Seed & Suchanek, 1992). Therefore, while good annual recruitment is possible, recovery of the mussel population may take up to 5 years. In certain circumstances and under some environmental conditions recovery may take significantly longer (Seed & Suchanek, 1992).

Tsuchiya & Nishihira (1986) examined young and older patches of *Mytilus edulis* in Japan, now thought to be *Mytilus galloprovincialis* (Seed, 1992).. They noted that as the patches of mussels grew older, individuals increased in size, and other layers were added, increasing the space within the matrix for colonization, which also accumulated biogenic sediment. Increased space and organic sediment was then colonized by infauna and epiphytes and, as the patches and mussels became older, eventually epizoic species colonized the mussel shells. Macroalgae could colonize at any time in the succession. Tsuchiya & Nishihira (1986) did not suggest a timescale. Colonization of the community associated with the mussel patches is therefore, dependant on the development of a mussel matrix, younger beds exhibiting lower species richness and species diversity than older beds, and hence growth rates and local environmental conditions.

Recovery of the rocky shore populations has been intensively studied after the *Torrey Canyon* oil spill in March 1967. Areas affected by oil alone recovered rapidly, within 3 years. But other sites suffered substantial damage due to the spilled oil and the application of aromatic hydrocarbon based dispersants. Populations of fucoids were abnormal for the first 11 years, and *Patella vulgata* populations were abnormal for at least 10-13 years. Recovery rates were dependant on local variation in recruitment and mortality so that sites varied in recovery rates, for example maximum cover of fucoids occurred within 1-3 years, barnacle abundance increased in 1-7 years, limpet number were still reduced after 6-8 years and species richness was regained in 2 to >10 years. Overall, recovery took 5-8 years on many shores but was estimated to take about 15 years on the worst affected shores (Southward & Southward, 1978; Hawkins & Southward, 1992; Raffaelli & Hawkins, 1999).

Additional information

None

Preferences & Distribution

Habitat preferences

Depth Range	
Water clarity preferences	
Limiting Nutrients	Data deficient
Salinity preferences	Full (30-40 psu)
Physiographic preferences	Open coast
Biological zone preferences	Eulittoral
Substratum/habitat preferences	Bedrock
Tidal strength preferences	
Wave exposure preferences	Exposed, Extremely exposed, Moderately exposed, Very exposed
Other preferences	Wave exposure

Additional Information

Mussels dominate slow draining slopes or platforms, or steep and vertical surfaces where wave exposure keeps the surface damp, while barnacles can tolerate dryer conditions.

Species composition

Species found especially in this biotope

- *Aglaothamnion sepositum*
- *Ceramium shuttleworthianum*
- *Littorina neglecta*
- *Mytilus edulis*
- *Porphyra umbilicalis*
- *Semibalanus balanoides*

Rare or scarce species associated with this biotope

-

Additional information

The MNCR recorded 289 species within this biotope (JNCC, 1999) although not all species occur in all examples of the biotope. The species composition of this biotope is likely to be variable. The relative abundance of the *Mytilus edulis* and *Semibalanus balanoides* probably depends on stochastic variation in recruitment, environmental conditions, and physical disturbance (e.g. by storms). The upper and lower limits are transitional with other biotopes that will vary with location, e.g. where the lower limits is transitional with e.g. ELR.Him, EIR.Ala or ELR.Coff, species characteristic of the lower shore or sublittoral fringe will probably penetrate the lower limit of this biotope increasing species richness. This biotope resembles the patchy, *Mytilus edulis* 'islands' (now thought to be *Mytilus galloprovincialis* (Seed, 1992)) described by Tsuchiya & Nishihira (1985 & 1986) on rocky shores in Japan, who provide species lists for their habitats.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The biotope is characterized by patches of small *Mytilus edulis* and the barnacle *Semibalanus balanoides* and the sensitivity assessments specifically consider these species. The mussels are considered to be both characterizing and key structuring species as the patches of mussels provide habitat to red algae and other species. The red seaweeds, *Porphyra umbilicalis* and *Palmaria palmata* may grow on the mussels, while within the mussel patch small *Corallina officinalis*, *Mastocarpus stellatus* and *Ceramium* sp. may be present. Other species common on rocky shores may be present and these play a role in structuring the biological assemblage. The dogwhelk *Nucella lapillus* predates on mussels, while the grazers *Patella vulgata* and *Littorina* sp. will influence the abundance of algae by grazing germlings and adults. However these species are considered less significant than wave action in structuring the assemblage.

Resilience and recovery rates of habitat

The characterizing species, mussels, *Mytilus edulis* and the barnacle *Semibalanus balanoides*, are sessile, attached organisms. Therefore, the only mechanism for recovery of populations from significant impacts (where resistance is assessed as None, Low or Medium) is larval recruitment to the impacted area.

Both mussels and barnacles are common, widespread species that spawn annually producing pelagic larvae that can disperse over long distances.The production of large numbers of larvae with high dispersal potential during the plantonic phase aids recovery. Long distance recolonization of areas by *Semibalanus balanoides*, with a range expansion of 20-25 km/year, was observed by Wethey *et al*., 2011, following recruitment failures. It is therefore likely that larval supply to impacted areas will provide high numbers of potential recruits. However, a range of factors influence whether there will be successful recruitment within a year..

Mainwaring *et al*. (2014) reviewed the evidence for recovery of *Mytilus edulis* beds (not clumps) from disturbance. Seed & Suchanek (1992) reviewed studies on the recovery of 'gaps' in *Mytilus* spp. beds. It was concluded that beds lower on the shore and at more exposed sites took longer to recover after a disturbance event than beds found high on the shore or at less exposed sites. In some long-term studies of *Mytilus californianus* it was observed that gaps could continue to increase in size post disturbance due to wave action and predation (Paine & Levin 1981; Brosnan &Crumrine 1994; Smith & Murray 2005) potentially due to the weakening of the byssus threads leaving them more vulnerable to environmental conditions (Denny 1987). Brosnan & Crumrine (1994) observed little recovery of the congener *Mytilus californianus* in two years after trampling disturbance. Petraitis & Dudgeon (2005) found that 5 years after the clearance of the dominant species *Ascophyllum nodosum* from experimental plots on shores in the Gulf of Maine, *Mytilus edulis* covered less than 1% on average of plots.

On rocky shores, barnacles are often quick to colonize available gaps, although a range of factors, as outlined above, will influence whether there is a successful episode of recruitment in a year to re-populate a shore following impacts. Bennell (1981) observed that barnacles that were removed when the surface rock was scraped off in a barge accident at Amlwch, North Wales returned to pre-accident levels within 3 years. Petraitis & Dudgeon (2005) also found that *Semibalanus balanoides* quickly recruited (present a year after and increasing in density) to experimentally cleared areas within the Gulf of Maine, that had previously been dominated by *Ascophyllum* *nodosum* However, barnacle densities were fairly low (on average 7.6 % cover) as predation levels in smaller patches were high and heat stress in large areas may have killed a number of individuals (Petraitis *et al*., 2003). Following creation of a new shore in the Moray Firth, *Semibalanus balanoides* did not recruit in large numbers until 4 years after shore creation (Terry & Sell, 1986).

In *Mytilus edulis* spawning occurs in spring and later summer allowing two periods of recruitment (Seed 1969). *Mytilus edulis* has a high fecundity producing >1,000,000 eggs per spawning event. Larvae stay in the plankton for between 20 days to two months depending on water temperature (Bayne 1976). In unfavourable conditions they may delay metamorphosis for 6 months (Lane *et al*., 1985). Larval dispersal depends on the currents and the length of time they spend in the plankton. Larvae subject to ocean currents for up to six months can have a high dispersal potential. Settlement occurs in two phases, an initial attachment using their foot (the pediveliger stage) and then a second attachment by the byssus thread before which they may alter their location to a more favourable one (Bayne, 1964). The final settlement often occurs around or between individual mussels of an established population. Larval mortality in *Mytilus edulis* can be as high as 99% due to adverse environmental conditions, especially temperature, inadequate food supply (fluctuations in phytoplankton populations), inhalation by suspension feeding adult mytilids, difficulty in finding suitable substrata and predation (Lutz & Kennish 1992).

Semibalanus balanoides may reproduce within their first year if they experience rapid growth (Moore 1936, Southward 1967). *Semibalanus balanoides* brood egg masses over autumn and winter and release the nauplii larvae during spring or early summer, to coincide with phytoplankton blooms on which the larvae feed. Local environmental conditions, including surface roughness (Hills & Thomason, 1998), wind direction (Barnes, 1956), shore height, wave exposure (Bertness *et al*., 1991) and tidal currents (Leonard *et al*., 1998) have been identified, among other factors, as factors affecting settlement of *Semibalanus balanoides*. Biological factors such as larval supply, competition for space, presence of adult barnacles (Prendergast *et al*., 2009 and the presence of species that facilitate or inhibit settlement (Kendall, *et al*., 1985, Jenkins *et al*., 1999) also play a role in recruitment. Mortality of juveniles can be high but highly variable, with up to 90 % of *Semibalanus balanoides* dying within ten days (Kendall *et al*., 1985).

Successful recruitment of high number of individuals to replenish the population may be episodic from both *Mytilus edulis* (Diederich, 2005) and *Semibalanus balanoides*, (Kendall *et al*., 1985). After settlement the juveniles are subject to high levels of predation as well as dislodgement from waves and sand abrasion depending on the area of settlement. Predation rates are variable (see Petraitis *et al*., 2003) and are influenced by a number of factors including the presence of algae (that shelters predators such as the dog whelk, *Nucella lapillus*, and the shore crab, *Carcinus maenas* and the sizes of clearings (as predation pressure is higher near canopies (Petraitis *et al*., 2003). *Semibalanus balanoides* may live up to four years in higher areas of the shore (Wethey,1985), On the lower shore, *Mytilus edulis* generally only survive between 2-3 years due to high predation levels, whereas higher up on the shore a wider variety of age classes are found (Seed, 1969). These short lifespans indicate that, following successful recolonization a typical; age-structured population could develop within four years or less.

Recovery rates of other species within the assemblage will be influenced by similar factors. The recovery of the red algae associated with *Mytilis edulis* patches will obviously depend on the recovery of the mussels. The presence of small Mytilus edulis and light coverings of algae also enhance settlement of the limpet *Patella vulgata* (Lewis & Bowman, 1975).

Resilience assessment. No evidence for recovery rates were found specifically for this biotope and

there is little evidence for recovery of *Mytilus edulis* beds to inform potential recovery of small clumps. The evidence for recovery rates of *Mytilus edulis* beds from different levels of impact is very limited and whether these rates are similar or not between biotopes is largely unclear. The *Mytilus edulis* clumps characterizing this biotope are likely to be relatively short-lived compared to substantial *Mytilus edulis* beds, due to high rates of predation on the lower shore.
Overall, *Mytilus* spp. populations are considered to have a strong ability to recover from environmental disturbance (Holt *et al*, 1998; Seed & Suchaneck, 1992). However, this cannot always be guaranteed within a certain time-scale due to the episodic and patchy nature of *Mytilus edulis* and *Semibalanus balanoides* recruitment (Lutz & Kennish 1992; Seed & Suchanek 1992; Seed, 1969, Terry & Sell, 1986) and the influence of site-specific variables (Seed, 1969). The evidence suggests that the size of the footprint of an impact and the magnitude will influence the recovery rates by mediating settlement and post-settlement recruitment. Both barnacles and *Mytilus edulis* are attracted to settle in the presence of adults of the same species (Crisp, 1961;Seed, 1969; Hills & Thomason, 1996), so that the presence of adults will facilitate recovery. The presence of filamentous red seaweeds will also enhance *Mytilus edulis* recruitment (Seed, 1969). Resilience is assessed as 'High' (within 2 years) where resistance is 'Medium' (<25% of characteristic biotope removed). A resistance of medium assumes that either a large proportion of the biotope in unimpacted or that the entire biotope is impacted but only a proportion of the characterizing species are removed, with unimpacted areas or individuals supporting recovery. Resilience is assessed as 'Medium' (2-10 years) where resistance is 'None' or 'Low', as recruitment may be episodic in both barnacles and mussels and as recovery to a full age structure may require more than 2 years. However, as *Mytilus edulis* are generally small within this biotope and *Semibalanus balanoides* have a relatively short lifespan, the time taken for recovery is considered to be towards the lower end of the range.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

The barnacle *Semibalanus balanoides* is primarily a 'northern' species with an arctic-boreal distribution. Long-term time series show that recruitment success is correlated to sea temperatures (Mieszkowska, *et al*., 2014) Due to warming temperatures its range has been contracting northwards. Temperatures above 10 to 12 °C inhibit reproduction (Barnes, 1957, 1963, Crisp & Patel, 1969) and laboratory studies suggest that temperatures at or below 10°C for 4-6 weeks are required in winter for reproduction, although the precise threshold temperatures for reproduction are not clear (Rognstad *et al*., 2014). Observations of recruitment success in *Semibalanus balanoides* throughout the South West of England, strongly support the hypothesis that an extended period (4-6 weeks) of sea temperatures <10 °C is required to ensure a good supply of larvae (Rognstad *et al*., 2014, Jenkins *et al*., 2000). Adults may be able to tolerate an acute or chronic change, however, if an acute change in temperature occurred in winter it could disrupt reproduction while a chronic change could alter reproductive success if it exceeded thermal thresholds for reproduction. The effects would depend on the magnitude, duration, and footprint of the activities leading to this pressure. During periods of high reproductive success linked to cooler temperatures the range of barnacles can increase with range extensions in the order of 25 km (Wethey *et al*., 2011), and 100 km (Rognstad *et al*., 2014) were observed.

Mytilus edulis is a eurytopic species found in a wide temperature range from mild, subtropical regions to areas which frequently experience freezing conditions and are vulnerable to ice scour (Seed & Suchanek 1992). In British waters 29°C was recorded as the upper sustained thermal tolerance limit for *Mytilus edulis* (Read & Cumming, 1967; Almada-Villela, *et al*., 1982), although it is thought that European mussels will rarely experience temperatures above 25°C (Seed & Suchanek, 1992). At the upper range of a mussels tolerance limit, heat shock proteins are produced, indicating high stress levels (Jones *et al*., 2010). After a single day at 30°C, heat shock proteins were still present over 14 days later, although at a reduced level. Increased temperatures can also affect reproduction in *Mytilus edulis* (Myrand *et al*., 2000). In shallow lagoons mortality began in late July at the end of a major spawning event when temperatures peaked at >20°C. These mussels had a low energetic content post spawning and had stopped shell growth. It is likely that the high temperatures caused mortality due to the reduced condition of the mussels post-spawning (Myrand *et al*., 2000). Gamete production does not appear to be affected by temperature (Suchanek, 1985).

Power stations have the potential to cause an increase in sea temperature of up to 15°C (Cole *et al*., 1999), although this impact will be localised. However, as mussels are of the most damaging biofouling organisms on water outlets of power stations, they are clearly not adversely affected (Whitehouse *et al*., 1985; Thompson *et al*., 2000).

Most of the other species within the biotope are eurythermal (e.g. *Patella vulgata* and *Nucella lapillus*) and are hardy intertidal species that tolerate long periods of exposure to the air and consequently wide variations in temperature. In addition, most species are distributed to the north of south of the British Isles and unlikely to be adversely affected by long-term temperature changes at the benchmark level. *Corallina officinalis*, however, experienced severe damage during the unusually hot summer of 1983 (Hawkins & Hartnoll, 1985).

Sensitivity assessment. Based on the wide range of temperature tolerance of *Mytilus edulis* and its limited effect on its physiology, it is concluded that the acute and chronic changes described by the benchmark would have no effect unless an acute change exceeded thermal tolerances in summer. Increased temperatures are likely to favour chthamalid barnacles rather than *Semibalanus balanoides* (Southward *et al*. 1995). *Chthamalus montagui* and *Chthamalus stellatus* are warm water species, with a northern limit of distribution in Britain so are likely to be tolerant of long-term increases in temperature, while *Semibalanus balanoides* is boreal and at its southern limit the British Isles. Thus, an increase in temperature may lead to a change in the dominant species of barnacle. However, barnacle populations are highly connected, with a good larval supply and high dispersal potential (Wethey *et al*., 2011, Rognstad *et al*., 2014). Therefore, larvae are likely to be supplied by local populations to counteract local reproductive failures and resistance is therefore assessed as 'High' and resilience as 'High' (by default). This biotope is therefore considered to be 'Not sensitive' at the pressure benchmark. Sensitivity to longer-term, broad-scale perturbations such as increased temperatures from climate change would, however, be greater, based on the extent of the impact.

Temperature decrease (local)	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

Many intertidal species are tolerant of freezing conditions as they are exposed to extremes of low air temperatures during periods of emersion. They must also be able to cope with sharp temperature fluctuations over a short period of time during the tidal cycle. In winter air temperatures are colder than the sea, conversely in summer air temperatures are much warmer than the sea. Species that occur in the intertidal are therefore generally adapted to tolerate a range of temperatures, with the width of the thermal niche positively correlated with the height of the shore that the animal usually occurs at (Davenport & Davenport, 2005).

The barnacle *Semibalanus balanoides* is primarily a 'northern' species with an arctic-boreal distribution. Long-term time series show that recruitment success is correlated to lower sea temperatures (Mieszkowska *et al*., 2014). Due to warming temperatures its range has been contracting northwards. Temperatures above 10 to 12 °C inhibit reproduction (Barnes, 1957, 1963, Crisp & Patel, 1969) and laboratory studies suggest that temperatures at or below 10 °C for 4-6 weeks are required in winter for reproduction, although the precise threshold temperatures for reproduction are not clear (Rognstad *et al*., 2014).

Mytilus edulis is a eurytopic species found in a wide temperature range and in areas which frequently experience freezing conditions and are vulnerable to ice scour (Seed & Suchanek 1992). After acclimation of individuals of Mytilus edulis to 18°C, Kittner & Riisgaard (2005) observed that the filtrations rates were at their maximum between 8.3 and 20 °C and below this at 6 °C the mussels closed their valves. However, after being acclimated at 11 °C for five days, the mussels maintained the high filtration rates down to 4 °C. Hence, given time, mussels can acclimatise and shift their temperature tolerance. Filtration in *Mytilus edulis* was observed to continue down to -1 °C, with high absorption efficiencies (53-81 %) (Loo, 1992).

The tolerance of *Semibalanus balanoides* collected in the winter (and thus acclimated to lower temperatures) to low temperatures was tested in the laboratory. The median lower lethal temperature tolerance was -14.6 °C (Davenport & Davenport, 2005) A decrease in temperature at the pressure benchmark is therefore unlikely to negatively affect this species. The same series of experiments indicated that median lower lethal temperature tolerances for *Mytilus edulis* was -8.2 °C . A decrease in temperature at the pressure benchmark is therefore unlikely to negatively affect these species.

Sensitivity assessment. Based on the wide temperature tolerance range of *Mytilus edulis* and its limited effect on its physiology, it is concluded that the acute and chronic changes described by the benchmark would have limited effect. Similarly, based on global temperatures and the link between cooler winter temperatures and reproductive success, *Semibalanus balanoides* is also considered to be unaffected at the pressure benchmark. Based on the characterizing species this biotope is considered to have 'High' resistance and 'High resilience (by default) to this pressure and is therefore considered to be 'Not sensitive'.

Salinity increase (local)	Low Q: High A: Low C: Medium	Medium Q: High A: Low C: Medium	Medium Q: Low A: Low C: Medium

Local populations may be acclimated to the prevailing salinity regime and may, therefore, exhibit different tolerances to other populations subject to different salinity conditions and therefore, caution should be used when inferring tolerances from populations in different regions. This biotope is found in full (30-35 ppt) salinity (Connor *et al*., 2004). Biotopes found in the intertidal will naturally experience fluctuations in salinity where evaporation increases salinity and inputs of rainwater expose individuals to freshwater. Species found in the intertidal are therefore likely to have some form of behavioural or physiological adaptations to changes in salinity.

Mytilus edulis is found in a wide range of salinities from variable salinity areas (18-35ppt) such as estuaries and intertidal areas, to areas of more constant salinity (30-35ppt) in the sublittoral

(Connor *et al*., 2004). Furthermore, mussels in rock pools are likely to experience hypersaline conditions on hot days. Newell (1979) recorded salinities as high as 42 psu in intertidal rock pools, suggesting that *Mytilus edulis* can tolerate high salinities.

The associated species are typically found in a range of salinities. *Corallina officinalis* is found in tide pools where salinities may fluctuate markedly during exposure to the air. Kinne (1971) cites maximal growth rates for *Corallina officinalis* between 33 and 38 psu in Texan lagoons. Laboratory experiments have defined the upper and lethal lower limits for *Palmaria palmata* as 15 psu and 50 psu, (Karsten *et al*., 2003) with optimal salinity defined as 23-34 psu (Robbins, 1978).

In the laboratory, *Semibalanus balanoides* was found to tolerate salinities between 12 and 50 psu (Foster, 1970). Young *Littorina littorea* inhabit rock pools where salinity may increase above 35psu. Thus, the associated species may be able to tolerate some increase in salinity.

Sensitivity assessment. Little direct evidence was found to assess sensitivity to this pressure. Although some increases in salinity may be tolerated by the associated species present these are generally short-term and mitigated during tidal inundation. This biotope is considered, based on the distribution of *Mytilus edulis*, and the associated red algal species on the mid to lower shore to be sensitive to a persistent increase in salinity to > 40 ppt. Resistance is therefore assessed as ‘Low’ and recovery as ‘Medium’ (following restoration of usual salinity). Sensitivity is therefore assessed as ‘Medium'.

Salinity decrease (local)	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

Mytilus edulis is found in a wide range of salinities from variable salinity areas (18-35 ppt) such as estuaries and intertidal areas, to areas of more constant salinity (30-35ppt) in the sublittoral (Connor *et al*., 2004). In addition, *Mytilus edulis* thrives in brackish lagoons and estuaries, although, this is probably due to the abundance of food in these environments rather than the salinity (Seed & Suchanek, 1992). *Mytilus edulis* was recorded to grow in a dwarf form in the Baltic sea where the average salinity was 6.5 psu (Riisgård *et al*., 2013). *Mytilus edulis* exhibits a defined behavioural response to reducing salinity, initially only closing its siphons to maintain the salinity of the water in its mantle cavity, which allows some gaseous exchange and therefore maintains aerobic metabolism for longer. If the salinity continues to fall the valves close tightly (Davenport ,1979; Rankin & Davenport, 1981). In the long-term (weeks) *Mytilus edulis* can acclimate to lower salinities (Almada-Villela, 1984; Seed & Suchanek, 1992; Holt *et al*.,1998). Almada-Villela (1984) reported that the growth rate of individuals exposed to only 13 psu reduced to almost zero but had recovered to over 80% of control animals within one month. Observed differences in growth are due to physiological and/or genetic adaptation to salinity.

Decreased salinity has physiological effects on *Mytilus edulis*; decreasing the heart rate (Bahmet *et al*., 2005), reducing filtration rates (Riisgård *et al*., 2013), reducing growth rate (Gruffydd *et al*., 1984) and reducing the immune function (Bussell *et al*., 2008). Both Bahmet *et al*., (2005); Riisgård *et al*., (2013) noted that filtration and heart rates return to normal within a number of days acclimation or a return to the original salinity. However, Riisgard *et al*., (2013) did observe that mussels from an average of 17 psu found it harder to acclimate between the salinity extremes than those from an average of 6.5 psu. This observation may mean that mussels in a variable/lower salinity environment are more able to tolerate change than those found at fully marine salinities. In extreme low salinities, e.g. resulting from storm runoff, large numbers of mussels may be killed (Keith Hiscock pers comm.). However, Bailey *et al*., (1996) observed very few mortalities when exposing *Mytilus edulis* to a range of salinities as low as 0ppt for two weeks at a range of temperatures. It was also noted that there was a fast recovery rate.

*Semibalanus balanoide*s are tolerant of a wide range of salinity and can survive periodic emersion in freshwater, e.g. from rainfall or freshwater run-off, by closing their opercular valves (Foster, 1971b). They can also withstand large changes in salinity over moderately long periods of time by falling into a "salt sleep".

Similarly, most of the characterizing species (e.g. *Littorina littorea* and *Patella vulgata*) are found in a wide range of salinities and are probably tolerant of variable or reduced salinity. The intertidal interstitial invertebrates and epifauna probably experience short-term fluctuating salinities, with reduced salinities due to rainfall and freshwater runoff when emersed. Prolonged reduction in salinity, e.g. from full to reduced due to e.g. freshwater runoff, is likely to reduce the species richness of the biotope due to loss of less tolerant red algae and some intolerant invertebrates. However, the dominant species will probably survive and the integrity of the biotope is likely to be little affected. Areas of freshwater runoff in the intertidal promote the growth of ephemeral greens, probably due to their tolerance of low salinities and inhibition of grazing invertebrates.

Sensitivity assessment. Based on reported distributions of *Mytilus edulis* and the results of experiments to assess salinity tolerance thresholds and behavioural and physiological responses in *Mytilus edulis and Semibalanus balanoides* it is considered that the benchmark decrease in salinity would not result in mortality of the characterizing species in biotopes that were previously fully marine. Resistance is therefore assessed as 'High' and resilience as 'High', based on no effect to recover from and the biotope is considered to be 'Not sensitive'.

Water flow (tidal current) changes (local)	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

Mytilus edulis biotopes are recorded from weak (<0.5 m/s) to strong (up to 3 m/s) tidal streams (Connor *et al*., 2004). Although this specific biotope is found in areas dominated by wave action, dense *Semibalanus balanoides* and *Mytilus edulis* populations occur in tidal estuaries in Maine, where peak, tidal flows are >1.1 m/s, (Leonard, *et al*., 1998) indicating the characterizing species are able to thrive in areas with high flows.

Flow rate has been shown to influence the strength and number of byssus threads that are produced by *Mytilus edulis* and other *Mytilus* spp. with mussels in areas of higher flow rate demonstrating stronger attachment (Dolmer & Svane, 1994; Alfaro, 2006). Young (1985) demonstrated that byssus thread production and attachment increased with increasing water agitation. Higher current speed brings food to the bottom layers of the water column, and hence near to the mussels, at a higher rate (Frechette *et al*., 1989). Widdows *et al*., (2002) found that there was no change in filtration rate of *Mytilus edulis* between 0.05 and 0.8 m/s and that above 0.8 m/s the filtration rate declined mainly because the mussels became detached from the substratum in the experimental flume tank. Widdows *et al*., (2002) noted that their results were consistent with field observations, as mussels show preferential settlement and growth in areas of high flow, They also reported that Jenner *et al*.,(1998; cited in Widdows *et al*., 2002) observed that biofouling of cooling water systems by mussels was only reduced significantly when mean current speeds reached 1.8-2.2 m/s and that mussels were absent at >2.9 m/s.

Growth and reproduction of *Semibalanus balanoides* are influenced by food supply and water velocity (Bertness *et al*., 1991). Laboratory experiments demonstrate that barnacle feeding behaviour alters over different flow rates but that barnacles can feed at a variety of flow speeds (Sanford *et al*., 1994). The flow tank used velocities of 0.03, 0.07 and 0.2 m/s and a higher proportion of barnacles fed at higher flow rates (Sanford *et al*., 1994). Feeding was passive, meaning the cirri are held out to the flow to catch particles; active beating of the cirri to generate feeding currents occurs in still water (Crisp & Southward, 1961). Field observations at sites in southern New England (USA) that experience a number of different measured flow speeds, found that barnacles from all sites responded quickly to higher flow speeds, with a higher proportion of individuals feeding when current speeds were higher. Barnacles were present at a range of sites, varying from sheltered sites with lower flow rates (maximum observed flow rates <0.06- 0.1 m/s), a bay site with higher flow rates (maximum observed flows 0.2-0.3 m/s) and open coast sites (maximum observed flows 0.2-0.4 m/s). Recruitment was higher at the site with flow rates of 0.2-0.3 m/s (although this may be influenced by supply) and at higher flow microhabitats within all sites. Both laboratory and field observations indicate that flow is an important factor with effects on feeding, growth and recruitment in *Semibalanus balanoides* (Sanford *et al*., 1994, Leonard *et al*., 1998).

Sensitivity assessment. The biotope is characteristic of extreme to moderate wave exposed conditions where water movement from wave action will greatly exceed the strength of any possible tidal flow. Based on the available evidence the characterizing species *Mytilus edulis* and *Semibalanus balanoides* are able to adapt to high flow rates and the biotope is therefore considered to be 'Not sensitive' to an increase in water flow. A decrease in water flow may have some effects on recruitment and growth, but this is not considered to be lethal at the pressure benchmark and resistance is therefore assessed as 'High' and resilience as 'High' by default so that the biotope is considered to be 'Not sensitive'. A decrease in water flow, exceeding the pressure benchmark, coupled with a decrease in wave action, may, however, alter the character of the biotope to LR.MLR.MusF.MytFR or LR.MLR.MusF.MytFves, where brown seaweeds were able to proliferate and the edible periwinkle *Littorina littorea* was able to colonize.

Emergence regime changes	Low Q: Low A: NR C: NR	Medium Q: High A: Low C: Medium	Medium Q: Low A: Low C: Low

Emergence regime is a key factor structuring this (and other) intertidal biotopes. Increased emergence may reduce habitat suitability for characterizing species through greater exposure to desiccation and reduced feeding opportunities for the mussels and barnacles which feed when immersed. *Semibalanus balanoides* is less tolerant of desiccation stress than *Chthamalus* barnacles species and changes in emergence may, therefore, lead to species replacement and the development of a *Chthamalus* sp. dominated biotope, more typical of the upper shore may develop. Records suggest that, typically, above this biotope on the shore there may be a *Verrucaria maura* zone, and sparse barnacle zone, or a denser barnacle and limpet zone. In addition, patches of the lichen *Lichina pygmaea* with the barnacle *Chthamalus montagui* may also occur above this biotope, particularly on southern shores. Changes in emergence may therefore eventually lead to the replacement of this biotope to one more typical of the upper shore.

Decreased emergence would reduce desiccation stress and allow the attached suspension feeders more feeding time. Predation pressure on mussels and barnacles is likely to increase where these are submerged for longer periods and to prevent colonisation of lower zones. *Semibalanus balanoides* was able to extend its range into lower zones when protected from predation by the dogwhelk, *Nucella lapillus* (Connell, 1961). Competition from large fucoids and red algal turfs can also prevent *Semibalanus balano*ides from extending into lower shore levels (Hawkins, 1983). The biotope is generally found above a zone of either mixed turf-forming red seaweeds), *Himanthalia elongata* or above the sublittoral fringe kelp *Alaria esculenta* zone (Connor *et al*., 2004). Decreased emergence is likely to lead to the habitat the biotope is found in becoming more suitable for the lower shore species generally found below the biotope, leading to replacement.

The mobile species present within the biotope, including *Nucella lapillus*, *Patella vulgata* and the littorinids would be able to relocate to preferred shore levels.

Sensitivity assessment. Where this biotope occurs on the mid-shore it will be more sensitive to increased emergence whereas lower shore examples may be more sensitive to decreased emergence as the changed conditions occur towards the margins of habitat tolerance. As emergence is a key factor structuring the distribution of animals on the shore, resistance to a change in emergence (increase or decrease) is assessed as ‘Low’. Recovery is assessed as ‘Medium’, and sensitivity is therefore assessed as 'Medium'.

Wave exposure changes (local)	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

No direct evidence was found to assess the sensitivity of this biotope to changes in wave exposure at the pressure benchmark. This biotope is recorded from locations that are judged to range from exposed to very exposed (Connor *et al*., 2004). The natural wave exposure range of this biotope is therefore considered to exceed changes at the pressure benchmark and this biotope is considered to have 'High' resistance and 'High' resilience (by default), to this pressure (at the benchmark). A decrease in wave action,exceeding the pressure benchmark, may however alter the character of the biotope to LR.MLR.MusF.MytFR or LR.MLR.MusF.MytFves, where brown seaweeds were able to proliferate and the edible periwinkle *Littorina littorea* was able to colonize.

Chemical Pressures

	Resistance	Resilience	Sensitivity
Transition elements & organo-metal contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Contamination at levels greater than the benchmark may impact this biotope. The effects of contaminants on *Mytilus edulis* species were extensively reviewed by Widdows & Donkin, (1992) and Livingstone & Pipe (1992). Heavy metals were reported to cause sublethal effects and occasionally mortalities in mixed effluents. Barnacles, however, may tolerate fairly high level of heavy metals in nature, for example they possess metal detoxification mechanisms and are found in Dulas Bay, Anglesey, where copper reaches concentrations of 24.5 µg/l, due to acid mine waste (Foster *et al*., 1978; Rainbow, 1984).

Hydrocarbon & PAH contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Hydrocarbon contamination, at levels greater than the benchmark, e.g. from spills of fresh crude oil or petroleum products, may cause significant loss of component species in the biotope, through impacts on individual species viability or mortality, and resultant effects on the structure of the community (Suchanek, 1993; Raffaelli & Hawkins, 1999).

- The effects of contaminants on *Mytilus edulis* species were extensively reviewed by Widdows & Donkin, (1992) and Livingstone & Pipe (1992), and summarised in the *MarLIN* review and Holt *et al.* (1998). Overall, hydrocarbon tissue burden results in decreased scope for growth and in some circumstances may result in mortalities, reduced abundance or extent of *Mytilus edulis* (see review).
- Littoral barnacles (e.g. *Semibalanus balanoides*) have a high resistance to oil (Holt *et al.*, 1995) but may suffer some mortality due to the smothering effects of thick oil (Smith, 1968).
- Gastropods (e.g. *Littorina littorea* and *Patella vulgata*) and especially amphipods have been shown to be particularly intolerant of hydrocarbon and oil contamination (see Suchanek, 1993).
- Similarly, laboratory studies of the effects of oil and dispersants on several red algae species (Grandy 1984 cited in Holt *et al.* 1995) concluded that they were all sensitive to oil/ dispersant mixtures, with little differences between adults, sporelings, diploid or haploid life stages. O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination.

Synthetic compound contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Synthetic compound contamination, at levels greater than the benchmark, is likely to have a variety of effects depending the specific nature of the contaminant and the species group(s) affected. Barnacles have a low resilience to chemicals such as dispersants, dependant on the concentration and type of chemical involved (Holt *et al.*, 1995). Hoare & Hiscock (1974) reported that the limpet *Patella vulgata* was excluded from sites within 100-150m of the discharge of acidified, halogenated effluent in Amlwch Bay. Limpets are also extremely intolerance of aromatic solvent based dispersants used in oil spill clean-up. During the clean-up response to the *Torrey Canyon* oil spill nearly all the limpets were killed in areas close to dispersant spraying. Viscous oil will not be readily drawn in under the edge of the shell by ciliary currents in the mantle cavity, whereas detergent, alone or diluted in sea water, would creep in much more readily and be liable to kill the limpet (Smith, 1968).

Red algae are probably intolerant of chemical contamination. O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil contamination, although the filamentous forms were the most sensitive. Laboratory studies of the effects of oil and dispersants on several red algae species, including *Palmaria palmata* (Grandy, 1984 cited in Holt *et al.*, 1995) concluded that they were all sensitive to oil/ dispersant mixtures, with little differences between adults, sporelings, diploid or haploid life stages. Cole *et al.* (1999) suggested that herbicides, such as simazina and atrazine were very toxic to macrophytes. In addition, Hoare & Hiscock (1974) noted that almost all red algae were excluded from Amlwch Bay, Anglesey by acidified halogenated effluent discharge.

Radionuclide contamination	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence.

Introduction of other substances	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed**.

De-oxygenation	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

Mytilus edulis is regarded as euryoxic, tolerant of a wide range of oxygen concentrations including zero (Zandee *et al.*, 1986; Wang & Widdows, 1991; Gosling, 1992; Zwaan de & Mathieu, 1992; Diaz & Rosenberg, 1995; Gray et al., 2002). Theede et al., (1969) reported LD50of 35 days for *Mytilus edulis* exposed to 0.21 mg/l O_2 at 10°C, which was reduced to 25 days with the addition of sulphide (50 mg/l $Na_2S.9H_2O$). Jorgensen (1980) observed, by diving, the effects of hypoxia (0.2 -1 mg/l) on benthic macrofauna in marine areas in Sweden over a 3-4 week period. Mussels were observed to close their shell valves in response to hypoxia and survived for 1-2 weeks before dying (Cole *et al.*, 1999; Jorgensen, 1980). All life stages show high levels of tolerance to low oxygen levels. *Mytilus edulis* larvae, for example, are tolerant down to 1.0ml/l, and although the growth of late stage larvae is depressed in hypoxic condition, the settlement behaviour does not seem to be affected (Diaz & Rosenberg 1995). Based on the available evidence *Mytilus edulis* are considered to be resistant to periods of hypoxia and anoxia although sub-lethal effects on feeding and growth may be expected.

Semibalanus balanoides can respire anaerobically, so they can tolerate some reduction in oxygen concentration (Newell, 1979). When placed in wet nitrogen, where oxygen stress is maximal and desiccation stress is low, *Semibalanus balanoides* have a mean survival time of 5 days (Barnes *et al.*, 1963).

Sensitivity assessment. *Mytilus edulis* is considered to be ‘Not Sensitive’ to de-oxygenation at the pressure benchmark. Resistance is therefore assessed as ‘High’ and resilience as ‘High’ (no effect to recover from), resulting in a sensitivity of 'Not sensitive'. However, as this biotope occurs in the intertidal, emergence will mitigate the effects of hypoxic surface waters as will the exposure to wave action and water flows and this pressure is considered to be 'Not relevant'.

Nutrient enrichment	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not sensitive Q: High A: High C: High

No direct evidenc ewas found to assess this pressure. A slight increase in nutrient levels could be beneficial for barnacles and mussels by promoting the growth of phytoplankton levels and therefore increasing zooplankton levels. Limpets and other grazers would also benefit from increased growth of benthic microalgae. However, Holt *et al.* (1995) predict that smothering of barnacles or mussels by ephemeral green algae is a possibility under eutrophic conditions.

Sensitivity assessment. The pressure benchmark is set at a level that is relatively protective and based on the evidence and considerations outlined above the biological assemblage, including the clumps of *Mytilus edulis*, are considered to be 'Not sensitive' at the pressure benchmark. Resistance and resilience are therefore assessed as 'High'.

Organic enrichment	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

Organic enrichment may lead to eutrophication with adverse environmental effects including deoxygenation, algal blooms and changes in community structure (see nutrient enrichment and de-oxygenation). No evidence was found for piddocks to support assessment of sensitivity to this pressure. *Mytilus edulis*, however, has been found to be generally insensitive to increased organic matter resulting from human activities. *Mytilus edulis* have been recorded in areas around sewage outflows (Akaishi *et al*. 2007; Lindahl & Kollberg, 2008; Nenonen *et al*. 2008; Giltrap *et al*. 2013) suggesting that they are highly tolerant of the increase in organic material that would occur in these areas. A number of studies have also highlighted the ability of *Mytilus edulis* to utilise the increased volume of organic material available at locations around salmon farms. Reid *et al*. (2010) noted that *Mytilus edulis* could absorb organic waste products from a salmon farm with great efficiency. Increased shell length, wet meat weight, and condition index were shown at locations within 200m from a farm in the Bay of Fundy allowing a reduced time to market (Lander *et al*., 2012). It has been shown that regardless of the concentration of organic matter *Mytilus edulis* will maintain its feeding rate by compensating with changes to filtration rate, clearance rates, production of pseudofaeces and absorption efficiencies (Tracey, 1988; Bayne *et al*., 1993; Hawkins *et al*., 1996).

The biotopes occurs in tide swept or wave exposed areas (Connor *et al*., 2004) preventing a build up of organic matter, so that the biotope is considered to have a low risk of organic enrichment at the pressure benchmark.

Sensitivity assessment. Based on the observation of *Mytilus edulis* thriving in areas of increased organic matter (Lander *et al*., 2012, Reid *et al*., 2010), it was assumed that *Mytilus edulis* clumps have a 'High' resistance to increased organic matter at the pressure benchmark. Resilience is therefore assessed as 'High' (no effect to recover from). No evidence was found to support an assessment for *Semibalanus balanoides*. As organic matter particles in suspension could potentially be utilised as a food resource or consumed by *Mytilus edulis* and other species present within the biotope with excess likely to be rapidly removed by wave action or coverall resistance of the biological assemblage within the biotope is considered to be 'High' and resilience was assessed as 'High', so that this biotope is judged to be 'Not sensitive'.

Physical Pressures

	Resistance	Resilience	Sensitivity
Physical loss (to land or freshwater habitat)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

All marine habitats and benthic species are considered to have a resistance of 'None' to this pressure and to be unable to recover from a permanent loss of habitat (resilience is ‘Very Low’). Sensitivity within the direct spatial footprint of this pressure is therefore ‘High’. Although no specific evidence is described confidence in this assessment is ‘High’, due to the incontrovertible nature of this pressure.

Physical change (to another seabed type)	None Q: High A: High C: High	Very Low Q: High A: Medium C: High	High Q: High A: High C: Medium

This biotope is characterized by the hard rock substratum to which barnacles and mussels can firmly attach. A change to a sedimentary substratum would significantly alter the character of the biotope. The biotope is, therefore, considered to have **None** resistance to this pressure, resilience is **Very low** (the pressure is a permanent change) and sensitivity is assessed as **High**.

Physical change (to another sediment type)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant to biotopes occurring on bedrock.

Habitat structure changes - removal of substratum (extraction)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

The species characterizing this biotope are epifauna or epiflora occurring on rock and would be sensitive to the removal of the habitat. However, extraction of rock substratum is considered unlikely and this pressure is considered to be ‘Not relevant’ to hard substratum habitats.

Abrasion/disturbance of the surface of the substratum or seabed	Low Q: High A: Medium C: High	Medium Q: High A: Medium C: High	Medium Q: High A: Medium C: High

The species characterizing this biotope, barnacles, mussels and attached red seaweeds are all attached and occur on the surface. They therefore have no protection from abrasion and can be damaged or killed or displaced. Displaced mussels may be able to reattach using byssus threads but barnacles have no mechanisms for reattachmnet if they survived removal. The level of effect will depend on the magnitude, extent and duration of the pressure.

The effects of trampling (a source of abrasion) on barnacles appears to be variable with some studies not detecting significant differences between trampled and controlled areas (Tyler-Walters & Arnold, 2008). However, this variability may be related to differences in trampling intensities and abundance of populations studied. The worst case incidence was reported by Brosnan and Crumrine (1994) who reported that a trampling pressure of 250 steps in a 20x20 cm plot one day a month for a period of a year significantly reduced barnacle cover at two study sites. Barnacle cover reduced from 66% to 7% cover in 4 months at one site and from 21% to 5% within 6 months at the second site. Overall barnacles were crushed and removed by trampling. Barnacle cover remained low until recruitment the following spring. Long et al. (2011) also found that heavy trampling (70 humans km^{-1} shoreline h^{-1}) led to reductions in barnacle cover.

Activities resulting in abrasion and disturbance can either directly affect the mussel by crushing them, or indirectly affect them by the weakening or breaking of their byssus threads making them vulnerable to displacement (Denny, 1987) where they are unlikely to survive (Dare, 1976). In addition, abrasion and sub-surface damage may attract mobile scavengers and predators including fish, crabs, and starfish to feed on exposed, dead and damaged individuals and discards (Kaiser & Spencer, 1994; Ramsay *et al*., 1998; Groenewold & Fonds, 2000; Bergmann *et al*., 2002). This effect will increase predation pressure on surviving damaged and intact *Mytilus edulis* when submerged. A number of activities or events that result in abrasion and disturbance and their impacts on mussel beds are described below, based on the review by Mainwaring *et al*. (2014).

Large declines of the *Mytilus californianus* from mussel beds due to trampling have been reported (Brosnan, 1993; Brosnan & Crumrine, 1994; Smith & Murray, 2005). Brosnan & Crumrine (1994) recorded the loss of 54% of mussels from a single experimental plot on one day. Mussels continued to be lost throughout the experimental period, forming empty patches larger than the experimental plots. The empty patches continued to expand after trampling had ceased, due to wave action. Brosnan (1993) also reported a 40% loss of mussels from mussel beds after three months of trampling, and a 50% loss within a year. Van de Werfhorst & Pearse (2007) examined *Mytilus californianus* abundance at sites with differing levels of trampling disturbance. The highest percentage of mussel cover was found at the undisturbed site while the severely disturbed site showed low mussel cover. Brosnan and Crumrine (1994) noted that mussels that occupied hard substrata but did not form beds were also adversely affected. Although only at low abundance (2.5% cover), all mussels were removed by trampling within 4 months. Brosnan & Crumrine (1994) noted that mussels were not common and confined to crevices in heavily trampled sites. Similarly, the mussel bed infauna (e.g. barnacles) was adversely affected, and were crushed or lost with the mussels to which they were attached. However, Beauchamp & Gowing (1982) did not observe any differences in mussel density between sites that differed in visitor use.

Collision of objects such as wave driven logs (or similar flotsam), is known to cause removal of patches of mussels from mussel beds (Seed & Suchanek, 1992; Holt et al., 1998). When patches occur in mussel beds a good recruitment could result in a rapid recovery or the patch may increase in size through weakening of the byssus threads of the remaining mussels leaving them vulnerable to erosion from storm damage (Denny, 1987). Damage in areas of high wave exposure is likely to result in increased erosion and a patchy distribution although recruitment may be high. In sheltered areas damage may take a lot longer due to limited larval supply, although the frequency of destruction through wave driven logs would be less than in high wave exposure. Similar effects could be observed through the grounding of a vessel, the dropping of an anchor or the laying of a cable, although the scale of damage clearly differs.Shifting sand is known to limit the range of Mytilus edulis through burial and abrasion (Daly & Mathieson, 1977).

Various fishing methods also result in abrasion of the mussel beds. Bait collection through raking will cause surface abrasion and the removal of patches of mussel resulting in the damage and recovery times described above. Holt et al., (1998) reported that hand collection, or using simple hand tools occurs in small artisanal fisheries. They suggested that moderate levels of collection by experienced fishermen may not adversely affect the biodiversity of the bed. But they also noted that even artisanal hand fisheries can deplete the mussel biomass on accessible beds in the absence of adequate recruitment of mussels. Smith & Murray (2005) observed a significant decrease in mussel mass (g/m^2), density (no./m^2), percentage cover and mean shell length due to low-intensity simulated bait-removal treatments (2 mussels / month) for 12 months (Smith & Murray, 2005). They also stated that the initial effects of removal were 'overshadowed' by loss of additional mussels during time periods between treatments, probably due to the indirect effect of weakening of byssal threads attachments between the mussel leaving them more susceptible to wave action (Smith & Murray, 2005). The low-intensity simulated bait-removal treatments had reduced percentage cover by 57.5% at the end of the 12 month experimental period. Smith & Murray (2005) suggested that the losses occurred from collection and trampling are far greater than those that occur by natural causes. This conclusion was reached due to significant results being displayed for human impact despite the experiment taking place during a time of high natural disturbance from El Niño–Southern Oscillation (ENSO).

Sensitivity assessment. Surface abrasion may remove mussel clumps and algae and *Semibalanus balanoides*. Resistance is therefore assessed as 'Low' for mussels, barnacles and algae. All components are predicted to remover within 2 -10 years, so that resilience is considered to be 'Medium' and sensitivity is 'Medium'.

Penetration or disturbance of the substratum subsurface	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

The species characterizing this biotope group are epifauna or epiflora occurring on rock which is resistant to subsurface penetration. The assessment for the abrasion pressure is therefore considered to equally represent sensitivity to this pressure.

Changes in suspended solids (water clarity)	High Q: High A: High C: Medium	High Q: High A: High C: High	Not sensitive Q: High A: High C: Medium

In general, increased suspended particles may enhance food supply (where these are organic in origin) or decrease feeding efficiency (where the particles are inorganic and require greater filtration efforts). Very high levels of silt may clog respiratory and feeding organs of the suspension feeding *Semibalanus balanoides* and *Mytilus edulis*. In addition, increased turbidity will decrease light penetration reducing photosynthesis by macroalgae within this biotope. Increased levels of particles may increase scour and deposition in the biotope depending on local hydrodynamic conditions, although changes in substratum are assessed through the physical change (to another seabed type) pressure.

A significant decrease in suspended organic particles may reduce food input to the biotope resulting in reduced growth and fecundity of suspension feeding barnacles and mussels. However, local primary productivity may be enhanced where suspended sediments decrease, increasing food supply. Decreased suspended sediment may increase macroalgal competition enhancing diversity but is considered unlikely to significantly change the character of the biotope as colonisation by larger brown macroalgae is limited by the friability of the surface which is unsuitable for attachment.

Macroalgae within the biotope may be sensitive to decreased light penetration, however Hily *et al*. (1992) found that, in conditions of high turbidity, the characterizing species *Ceramium virgatum* (as *Ceramium rubrum*) dominated sediments in the Bay of Brest, France. It is most likely that *Ceramium virgatum* thrived because other species of algae could not. Whilst the field observations in the Bay of Brest suggested that an increase in abundance of *Ceramium virgatum* might be expected in conditions of increased turbidity, populations where light becomes limiting will be adversely affected. However, in shallow depths and the intertidal, photosynthesis can occur during low tides (as long as sediments are not deposited) and *Ceramium virgatum* may benefit from increased turbidity through decreased competition. The other red algae species found within this biotope are considered to have similar tolerances based on tolerance of shade and/or eutrophic conditions.

Mytilus edulis are often found in areas with high levels of turbidity. For example, the average suspended particulate matter (SPM) concentration at Hastings Shingle Bank was 15 -20 mg/l in June 2005, reaching 50 mg/l in windier (force 4) conditions, although a concentration of 200 mg/l was recorded at this site during gales (Last et al., 2011). It may be possible for *Mytilus edulis* to adapt to a permanent increase in SPM by decreasing their gill size and increasing their palp size in areas of high turbidity (Theisen, 1982; Essink, 1999). In areas of variable SPM it is likely that the gill size would remain the same but the palp would adapt (Essink, 1999). Whilst the ability to adapt may prevent immediate declines in health, the energetic costs of these adaptations may result in reduced fitness; the extent of which is still to be established. Concentrations above 250 mg/l have been shown to impair the growth of filter-feeding organisms (Essink, 1999). But Purchon (1937) found that concentrations of particulates as high a 440 mg/l did not affect *Mytilus edulis* and that mortality was only occurred when mud was added to the experiment bringing the concentrations up to 1220 mg/l. The reason for some of the discrepancy between studies may be due to the volume of water used in the experiment. Loosanoff (1962) found that in small quantities of turbid water (due to particulates) the mussel can filter out all of the particulates within a few minutes whereas in volumes >50 gallons per individual the mussel becomes exhausted before the turbidity has been significantly lowered, causing it to close its shell and die. Based on a comprehensive literature review, Moore (1977) concluded that *Mytilus edulis* displayed a higher tolerance to high SPM concentrations than many other bivalves although the upper limit of this tolerance was not certain. He also hypothesised that the ability of the mussel to clean its shell in such conditions played a vital role in its success along with its pseudofaecal expulsion.

Mytilus edulis may be more sensitive to decreased turbidity where this reflects a decrease in the availability of organic matter and seston. Winter (1972) (cited by Moore, 1977) recorded 75% mortality of *Mytilus edulis* in concentrations of 1.84-7.36 mg/l when food was also available. However, a relatively small increase in SPM concentration e.g. from 10 mg/l to 90 mg/l was found to increase growth rates (Hawkins *et al*., 1996).

Gyory *et al*., (2013) found that increased turbidity triggered the release of larvae by *Semibalanus balanoides*, a response which may allow larval release to be timed with high levels of phytoplankton and at times where predation on larvae may be lowered due to the concentration of particles. Storm events that stir up sediments are also associated with larval release (Gyory & Pineda, 2011).

Sensitivity assessment. Evidence indicates that *Mytilus edulis* can tolerate a broad range of suspended solids. The benchmark for this pressure refers to a change in turbidity of one rank on the Water Framework Directive (WFD) scale. Mussel beds form in relatively clear waters of open coasts and wave exposed shores and on sediments in sheltered coast (where turbulent water flow over the mussel beds could resuspend sediments locally) and in turbid bays and estuaries. Therefore, is unlikely that a change in turbidity by of one rank (e.g. from 300 to 100 mg/l or <10 to 100 mg/l) will significantly affect the *Mytilus edulis* within this biotope. Resistance to this pressure is therefore assessed as ‘High. Recovery is assessed ‘High’ (no impact to recover from), and sensitivity is therefore 'Not sensitive'. The biotope is therefore considered to be ‘Not sensitive’. An indirect effect of increased turbidity and reduced light penetration may be reduced phytoplankton productivity which could reduce the food availability for suspension feeders. However, as *Mytilus edulis* use a variety of food sources and food is brought in from other areas with currents and tides, the effect is likely to be minimal. This species and the biotopes it forms are therefore not sensitive to changes in water clarity.

Smothering and siltation rate changes (light)	Medium Q: High A: High C: High	High Q: High A: Medium C: High	Low Q: High A: Medium C: High

Barnacle feeding may be affected however, wave action on rocky shores is likely to rapidly mobilise and remove deposits alleviating the effect of smothering. Barnacles have planktonic larvae so can recolonise affected area so recovery should be high (Hill, 2000). However, the lower limits of *Semibalanus balanoides* (as *Balanus balanoides*) appear to be set by levels of sand inundation on sand-affected rocky shores in New Hamshire (Daly & Mathieson, 1977).

Mytilus edulis occurs in areas of high suspended particulate matter (SPM) and therefore a level of siltation is expected from the settling of SPM. In addition, the high rate of faecal and pseudofaecal matter production by the mussels naturally results in siltation of the seabed, often resulting in the formation of large mounds beneath the mussel bed. For example, at Morecambe Bay an accumulation of mussel-mud (faeces, pseudofaeces and washed sand) of 0.4-0.5 m between May 1968 and September 1971 resulted in the mortality of young mussels (Daly & Mathieson, 1977). In order to survive the mussels needed to keep moving upwards to stay on the surface. Many individuals did not make it to the surface and were smothered by the accumulation of mussel-mud (Daly & Mathieson, 1977), so that whilst *Mytilus edulis* does have the capacity to vertically migrate through sediment some individuals will not survive.

Sand burial has been shown to determine the lower limit of *Mytilus edulis* beds (Daly & Mathieson, 1977). Burial of *Mytilus edulis* beds by large scale movements of sand, and resultant mortalities have been reported from Morecambe Bay, the Cumbrian coast and Solway Firth (Holt *et al*., 1998). Essink (1999) recorded fatal burial depths of 1-2 cm for *Mytilus edulis* and suggested that they had a low tolerance of sedimentation based on investigations by R.Bijkerk (cited by Essink, 1999). Essink (1999) suggested that deposition of sediment (mud or sand) on shallow mussel beds should be avoided. However, Widdows *et al*. (2002) noted that mussels buried by 6 cm of sandy sediment (caused by resuspension of sediment due to turbulent flow across the bed) were able to move to the surface within one day. Conversely, Condie (2009) (cited by Last *et al*., 2011) reported that *Mytilus edulis* was tolerant of repeated burial events.

Last *et al*., (2011) carried out burial experiments on *Mytilus edulis* in pVORTs. They used a range of burial depths and sediment fractions and temperatures. It was found that individual mussels were able to survive burial in depths of 2, 5 and 7 cm for over 32 days although the deeper and longer the mussels were buried the higher the mortality. Only 16% of buried mussels died after 16 days compared to almost 50% mortality at 32 days. Mortality also increased sharply with a decrease in particle size and with increases in temperature from 8.0 and 14.5 to 20 °C. The ability of a proportion of individuals to emerge from burial was again demonstrated with approximately one quarter of the individuals buried at 2 cm resurfacing. However, at depths of 5 cm and 7 cm no emergence was recorded (Last *et al*., 2011). The lower mortality when buried in coarse sands may be related to the greater number of individuals who were able to emerge in these conditions and emergence was to be significant for survival.

It is unclear whether the same results would be recorded when mussels are joined by byssal threads or whether this would have an impact on survival (Last *et al*., 2011), although Daly & Mathieson (1977) recorded loose attachments between juvenile mussels during a burial event and some of these were able to surface. It was not clear whether the same ability would be shown by adult mussels in a more densely packed bed.

Sensitivity assessment. *Semibalanus balanoides* is found permanently attached to hard substrates and is a suspension feeder. This species, therefore, has no ability to escape from silty sediments which would bury individuals and prevent feeding and respiration. The inability of *Mytilus edulis* to emerge from sediment deeper than 2 cm (Last *et al*., 2011, Essink, 1999, Daly & Matthieson, 1977) and the increased mortality with depth and reduced particle size observed by Last *et al*. (2011) suggest that some mussels may die if smothering is prolonged and resistance is assessed as 'Medium' for both *Mytilus edulis* and *Semibalanus balanoides*. Resilience is assessed as ‘High’ (recovery within 2 years) and sensitivity is, therefore, assessed as ‘Low’. Survival will be higher in winter months when temperatures are lower and physiological demands are decreased. It should be noted that the level of exposure may be reduced by wave action or water flows so that site-specific vulnerability will be negligible where sediments do not accumulate.

Smothering and siltation rate changes (heavy)	Low Q: High A: High C: High	Medium Q: High A: Medium C: High	Medium Q: High A: Medium C: High

Barnacle feeding may be affected however by smothering, wave action on rocky shores is likely to rapidly mobilise and remove deposits alleviating the effect of smothering. However, the lower limits of *Semibalanus balanoides* (as *Balanus balanoides*) appear to be set by levels of sand inundation on sand-affected rocky shores in New Hamshire (Daly & Mathieson, 1977).Sand burial has been shown to determine the lower limit of *Mytilus edulis* beds (Daly & Mathieson, 1977a). Burial of *Mytilus edulis* beds by large scale movements of sand, and resultant mortalities have been reported from Morecambe Bay, the Cumbrian coast and Solway Firth (Holt et al., 1998). Essink (1999) recorded fatal burial depths of 1-2 cm for *Mytilus edulis* and suggested that *Mytilus edulis* a low tolerance of sedimentation based on investigations by R.Bijkerk (cited by Essink, 1999). However, Widdows et al. (2002) noted that mussels buried by 6 cm of sandy sediment (caused by resuspension of sediment due to turbulent flow across the bed) were able to move to the surface within one day.

Last *et al*., (2011) carried out a series of burial experiments on *Mytilus edulis* in pVORTs using a range of burial depths, sediment fractions and temperatures. It was found that individual mussels were able to survive burial in depths of 2, 5 and 7cm for over 32 days although the deeper and longer the mussels were buried the higher the mortality. Only 16% of buried mussels died after 16 days compared to almost 50% mortality at 32 days. Mortality also increased sharply with a decrease in particle size and with increases in temperature from 8.0 and 14.5 to 20°C. The ability of a proportion of individuals to emerge from burial was again demonstrated, with approximately one quarter of the individuals buried at 2cm resurfacing. However, at depths of 5 cm and 7cm no emergence was recorded (Last et al., 2011). The lower mortality when buried in coarse sands may be related to the greater number of individuals who were able to emerge in these conditions.It is unclear whether the same results would be recorded when mussels are joined by byssal threads or whether this would have an impact on survival (Last *et al*., 2011), although Daly & Mathieson (1977) recorded loose attachments between juvenile mussels during a burial event and some of these were able to surface.

Sensitivity assessment. Sensitivity to this pressure will be mediated by site-specific hydrodynamic conditions and the footprint of the impact. Where a large area is covered sediments may be shifted by wave and tides rather than removed. The inability of *Mytilus edulis* to emerge from sediment deeper than 2 cm (Last et al., 2011, Essink, 1999, Daly & Matthieson, 1977) and the increased mortality with depth and reduced particle size observed by Last *et al*. (2011) indicates that there may be significant mortality of mussels where sediments persist. Resistance to siltation is therefore assessed as ‘Low’ for *Mytilus edulis and Semibalanus balanoides* and resilience is assessed as ‘Medium’ (2-10 years). Survival will be higher in winter months when temperatures are lower and physiological demands are decreased. However, mortality will depend on the duration of smothering, where wave action rapidly mobilises and removes fine sediments, survival will be muich greater.

Litter	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

Thompson *et al.*, (2004) demonstrated that *Semibalanus balanoides*, kept in aquaria, ingested microplastics within a few days. However, the effects of the microplastics on the health of exposed individuals have not been identified. *Mytilus edulis* also ingest microplastics. A laboratory experiment using microbeads of polystyrene, demonstrated uptake of particles by *Mytilus edulis* within 12 hours (Browne *et al.*, 2008). After three days some of the the beads were translocated to the circulatory system. Microplastics were excreted in fecal pellets but were still present in hemolymph 48 days later. No toxicological effects were observed and there were no changes in filter feeding activity (Browne *et al.*, 2008). As exposure was short-term it is not clear whether lethal or sub-lethal effects would occur in wild populations over extended periods. There is currently no evidence to assess the level of impact.

Electromagnetic changes	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence.

Underwater noise changes	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant. Wave action on exposed shores is likely to generate high levels of underwater noise. Other sources are not considered likely to result in effects on the biotope.

Introduction of light or shading	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

Semibalanus balanides sheltered from the sun grew bigger than unshaded individuals (Hatton, 1938; cited in Wethey, 1984), although the effect may be due to indirect cooling effects rather than shading. Barnacles are also frquently found under algal canopies suggesting that they are tolerant of shading. Light levels have also been demonstrated to influence a number of phases of the reproductive cycle in *Semibalanus balanoide*s. In general light inhibits aspects of the breeding cycle. Penis development is inhibited by light (Barnes & Stone, 1972) while Tighe-Ford (1967) showed that constant light inhibited gonad maturation and fertilization. Davenport & Crisp (unpublished data from Menai Bridge, Wales, cited from Davenport *et al.*, 2005) found that experimental exposure to either constant darkness, or 6 h light: 18 h dark photoperiods induced autumn breeding in *Semibalanus*. They also confirmed that very low continuous light intensities (little more than starlight) inhibited breeding. Latitudinal variations in timing of the onset of reproductive phases (egg mass hardening) have been linked to the length of darkness (night) experienced by individuals rather than temperature (Davenport *et al.*, 2005). Changes in light levels associated with climate change (increased cloud cover) were considered to have the potential to alter timing of reproduction (Davenport *et al*., 2005) and to shift the range limits of this species southward. However, it is not clear how these findings may reflect changes in light levels from artificial sources, and whether observable changes would occur at the population level as a result. There is, therefore, 'No evidence' on which to base an assessment.

Barrier to species movement	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

No direct evidence was found to assess this pressure. As the larvae of *mytilus edulis* and *Semibalanus balanoides* are planktonic and are transported by water movements, barriers that reduce the degree of tidal excursion may alter larval supply to suitable habitats from source populations. However the presence of barriers may enhance local population supply by preventing the loss of larvae from enclosed habitats. As both species are widely distributed and have larvae capable of long distance transport, resistance to this pressure is assessed as 'High' and resilience as 'High' by default. This biotope is therefore considered to be 'Not sensitive'.

Death or injury by collision	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant' to seabed habitats. NB. Collision by grounding vessels is addressed under 'surface abrasion.

Visual disturbance	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant.

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

This pressure is only relevant to the patches of *Mytilus edulis* as other species within the biotope are not subject to translocation or cultivation. Commercial cultivation of *Mytilus edulis* involves the collection of juvenile mussel 'seed' or spat (newly settled juveniles ca 1-2cm in length) from wild populations, with subsequent transportation around the UK for re-laying in suitable habitats. As the seed is harvested from wild populations from various locations the gene pool will not necessarily be decreased by translocations. Movement of mussel seed has the potential to transport pathogens and non-native species (see relevant pressure sections). This pressure assessment is based on Mainwaring *et al*. (2014) and considers the potential impacts on natural mussel beds of genetic flow between translocated stocks and wild mussel beds.

Two species of *Mytilus* occur in the

UK, *Mytilus edulis* and *Mytilus galloprovincialis*. *Mytilus edulis* appears to maintain genetic homogeneity throughout its range whereas *Mytilus galloprovincialis* can be genetically subdivided into a Mediterranean group and an Atlantic group (Beaumont *et al.* 2007). *Mytilus edulis* and *Mytilus galloprovincialis* have the ability to hybridise in areas where their distribution overlaps e.g. around the Atlantic and European coast (Gardner, 1996; Daguin *et al.*, 2001; Bierne *et al.*, 2002; Beaumont *et al.*, 2004). In the UK overlaps occur on the North East coast, North East Scotland, South West England and in the North, West and South of Ireland (Beaumont *et al.*, 2007). It is difficult to identify *Mytilus edulis*, *Mytilus galloprovincialis* or hybrids based on shell shape because of the extreme plasticity of shape exhibited by mussels under environmental variation, and a genetic test is required (Beaumont *et al.*, 2007). There is some discussion questioning the distinction between the two species as the hybrids are fertile (Beaumont *et al.*, 2007). Hybrids reproduce and spawn at a similar time to both *Mytilus edulis* and *Mytilus galloprovincialis* which supports genetic flow between the taxa (Doherty *et al.*, 2009).

There is some evidence that hybrid larvae have a faster growth rate to metamorphosis than pure individuals which may leave pure individuals more vulnerable to predation (Beaumont *et al.*, 1993). As the physiology of both the hybrid and pure *Mytilus edulis* is so similar there is likely to be very little impact on the tolerance of the bed to pressures nor a change in the associated fauna.

A review by Svåsand *et al.* (2007) concluded that there was a lack of evidence distinguishing between different populations to accurately assess the impacts of hybridisation and in particular how the gene flow may be affected by aquaculture. Therefore, it cannot be confirmed whether farming will have an impact on the genetics of this species beyond a potential for increased hybridisation.

Sensitivity assessment. No direct evidence was found regarding the potential for negative impacts of translocated mussel seed on wild *Mytilus edulis* populations. While it is possible that translocation of mussel seed could lead to genetic flow between cultivated beds and local wild populations, there is currently no evidence to assess the impact (Svåsand *et al.*, 2007). Hybrids would perform the same ecological functions as *Mytilus edulis* so that any impact relates to genetic integrity of a bed alone. This impact is considered to apply to all mussel biotopes equally, as the main habitat forming species *Mytilus edulis* is translocated. Also, given the uncertainty in identification of the species, habitats or biotopes that are considered to be characterized by *Mytilus edulis* may in fact contain *Mytilus galloprovincialis*, their hybrids or a mosaic of the three. Presently, there is no evidence of impact resulting from genetic modification and translocation on *Mytilus edulis* beds in general or the clumps that characterize this biotope.

Introduction or spread of invasive non-indigenous species	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

Recent evidence reviews have indicated that *Magallana gigas* is likely to be the most significant invasive non-indigenous species threatening littoral mussel aggregations (Sewell *et al.* 2008; Mainwaring *et al.* 2014) *Magallana gigas* is reported to out-compete and replace mussel beds in the intertidal and was predicted to do so, on both soft sediment and rocky habitats of low or high energy (Padilla, 2010). As oyster reefs form on former mussel beds, the available habitat for *Mytilus edulis* could be restricted (Diederich, 2006). It has been observed that mussel beds in the Wadden Sea that are adjacent to oyster farms were quickly converted to oyster beds (Kochmann *et al.*, 2008). However, there is no evidence that *Magallana gigas* is outcompeting

Mytilus edulis on very exposed rocky shores. The South American mytilid *Aulocomya ater* was reported recently in the Moray Firth, Scotland in 1994 and again in 1997 (McKay, 1994; Holt *et al.*, 1998; Eno *et al.*, 1997). *Aulocomya ater* is thought to have a stronger byssal attachment than *Mytilus edulis* and may replace *Mytilus edulis* in more exposed areas if it reproduces successfully (Holt *et al.*, 1998). However, there is no evidence of competition at present.

The Australasian barnacle *Austrominius* (previously *Elminius) modestus* was introduced to British waters on ships during the second world war. However, its overall effect on the dynamics of rocky shores has been small as *Austrominius modestus* has simply replaced some individuals of a group of co-occurring barnacles (Raffaelli & Hawkins, 1999). Although present, monitoring indicates it has not outnumbered native barnacles in the Isle of Cumbrae (Gallagher *et al.*, 2015) although it may dominate in estuaries (Gomes-Filho, *et al.*, 2010).

Sensitivity assessment. Overall, there is little evidence of this biotope being adversely affected by non-native species, resistance is therefore assessed as 'High', and resilience as 'High' (by default), and the biotope is considered to be 'Not sensitive'.

Introduction of microbial pathogens	Medium Q: High A: Low C: Low	High Q: High A: Low C: Medium	Low Q: High A: Low C: Low

Mytilus species host a wide variety of disease organisms. parasites and commensals from many animal and plant groups including bacteria, blue green algae, protozoa, boring sponges, boring polychaetes, boring lichen, the intermediary life stages of several trematodes, the copepod *Mytilicola intestinalis* (red worm disease) and decapods e.g. the pea crab *Pinnotheres pisum* (Bower, 1992; Bower & McGladdery, 1996). Bower (1992) noted that mortality from parasitic infestation in *Mytilus* sp. was lower than in other shellfish in which the same parasites or diseases occurred. Mortality may result from the shell boring species such as the polychaete *Polydora ciliata* or sponge *Cliona celata*, which weaken the shell increasing the mussels vulnerability to predation. Barnacles are parasitised by a variety of organisms and, in particular, the cryptoniscid isopod *Hemioniscus balani* , in which heavy infestation can cause castration of the barnacle. At usual levels of infestation these are not considered to lead to high levels of mortality and these are not considered by the sensitivity assessment. Outbreaks of Bonamia may cause significant mortalities in some shellfish populations but this protozoan has been shown not to infect Mytilus edulis (Culloty *et al.*, 1999).

Marteilia refringens can infect and have significant impacts on the health of *Mytilus edulis*. There is some debate as to whether there are two species of Marteilia, one which infects oysters (*Marteilia refringens*) and another that infects blue mussels (*Marteilia maurini*) (Le Roux et al., 2001) or whether they are just two strains of the same species (Lopez-Flores *et al.*,2004; Balseiro *et al.*, 2007). Both species are present in southern parts of the United Kingdom. The infection of *Marteilia* results in Marteiliosis which disrupts the digestive glands of *Mytilus edulis* especially at times of spore release. Heavy infection can result in a reduced uptake of food, reduced absorption efficiency, lower carbohydrate levels in the haemolymph and inhibited gonad development particularly after the spring spawning resulting in an overall reduced condition of the individual (Robledo *et al.*, 1995). Recent evidence suggests that *Marteilia* is transferred to and from *Mytilus edulis* via the copepod *Paracartia grani*. This copepod is not currently prevalent in the UK waters, with only a few records in the English Channel and along the South coast. However, it is thought to be transferred by ballast water and so localised introductions of this vector may be possible in areas of mussel seed transfer. The mussel populations here are considered to be naive (i.e. not previously exposed) and therefore could be heavily affected, although the likelihood is slim due to the dependence on the introduction of a vector that is carrying Marteilia and then it being transferred to the mussels.

Berthe *et al*. (2004) concluded that *Mytilus edulis* is rarely significantly affected by *Marteilia* sp. However, occasions have been recorded of nearly 100% mortality when British spat have been transferred from a 'disease free area' to areas in France were *Marteilia* sp. are present. This suggests that there is a severe potential risk if naive spat are moved around the UK from northern waters into southern waters where the disease is resident (enzootic) or if increased temperatures allow the spread of *Marteilia* sp. northwards towards the naive northern populations. In addition, rising temperatures could allow increased densities of the *Marteilia* sp. resulting in heavier infections which can lead to mortality.

Sensitivity assessment. This assessment solely consideres the sensitivity of *Mytilus edulis*. Bower (2010) noted that although *Marteilia* was a potentially lethal pathogen of mussels, most populations were not adversely affected by marteilioisis but that in some areas mortality can be significant in mariculture (Berthe *et al*., 2004). The resultant population would be more sensitive to other pressures, even where the disease only resulted in reduced condition. The removal of clumps of *Mytilus edulis* would alter the character of the biotope and therefore, a precautionary resistance of 'Medium' to this pressure is suggested (<25% mortality), with a resilience of 'High' (recovery within 2 years) resulting in a 'Low' overall score for sensitivity.

Removal of target species	Low Q: Low A: NR C: NR	Medium Q: High A: Medium C: High	Medium Q: Low A: Low C: Low

The characterizing species *Mytilus edulis* is too small and patchy in this biotope to be targeted for commercial harvesting. However, some hand-gathering of this species and the edible periwinkle *Littorina littorea* may occur. As *Littorina littorea* are present only in low densities and the biotope is wave exposed, ecological effects such as the proliferation of algae are not predicted to arise from its removal.

Sensitivity assessment. Removal of a large percentage of *Mytilus edulis* by handgatherers would alter the character of the biotope, so that it was more typical of the biotopes, LR.HLR.MusB.Cht.Cht or LR.HLR.MusB.Sem. Resistance is therefore assessed as 'Low' and recovery as 'Medium', so that sensitivity is assessed as 'Medium'.

Removal of non-target species	Medium Q: Low A: NR C: NR	Low Q: High A: Medium C: High	Medium Q: Low A: Low C: Low

The characterizing species *Mytilus edulis* is likely to be too small and patchy in this biotope to be targeted for commercial harvesting. However, some hand-gathering of this species and the edible periwinkle *Littorina littorea* may occur. As *Littorina littorea* are present only in low densities and the biotope is wave exposed, ecological effects such as the proliferation of algae are not predicted to arise from its removal. Removal of the characterizing species, *Mytilus edulis* and barnacles and the red seaweeds accidentally would alter the character of the biotope. The ecological services such as filtation and primary and secondary production provided by these species would also be lost.

Sensitivity assessment. Removal of a large percentage of the characterising species hwould alter the character of the biotope, so that it was bare rock. Resistance is therefore assessed as ‘Low’ and recovery as ‘Medium’, so that sensitivity is assessed as ‘Medium’.

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