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Hydroids, ephemeral seaweeds and *Littorina littorea* in shallow eulittoral mixed substrata pools

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

Dr Heidi Tillin & Charlotte Marshall

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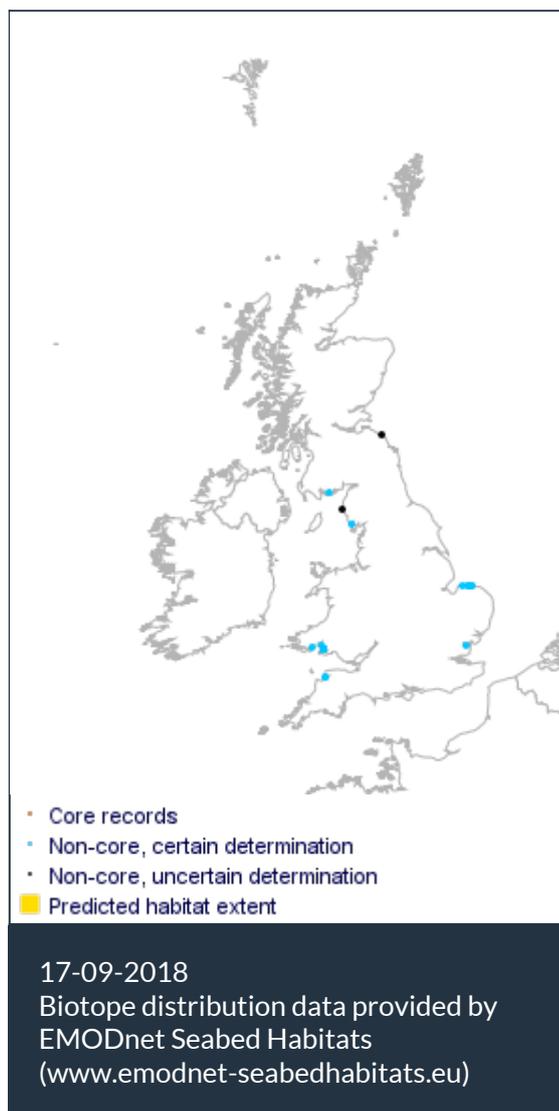
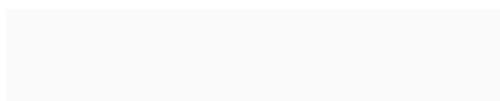
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Researched by Dr Heidi Tillin & Charlotte Marshall

Refereed by This information is not refereed.

Summary

☰ UK and Ireland classification

EUNIS 2008	A1.414	Hydroids, ephemeral seaweeds and <i>Littorina littorea</i> in shallow eulittoral mixed substrata pools
JNCC 2015	LR.FLR.Rkp.H	Hydroids, ephemeral seaweeds and <i>Littorina littorea</i> in shallow eulittoral mixed substrata pools
JNCC 2004	LR.FLR.Rkp.H	Hydroids, ephemeral seaweeds and <i>Littorina littorea</i> in shallow eulittoral mixed substrata pools
1997 Biotope	LR.LR.Rkp.H	Hydroids, ephemeral seaweeds and <i>Littorina littorea</i> in shallow eulittoral mixed substrata pools

🔍 Description

Shallow pools on mixed cobbles, pebbles, gravel and sand characterized by abundant hydroids. Species present may include *Obelia geniculata*, *Obelia dichotoma*, *Obelia longissima*, *Sertularia*

cupressina, *Tubularia indivisa* and *Thuiaria thuja*. The difficulty in identifying hydroids suggests many more species may be also be present. Other species typically found in this biotope include ephemeral green algae (*Ulva* sp.), red algae (*Chondrus crispus* and Coralline algae) and the winkle *Littorina littorea*. Within the pools, patches of sand may be occupied by the lugworm *Arenicola marina* and sand mason worms *Lanice conchilega*. These pools are often associated with mussel beds (MytX), with *Mytilus edulis* frequently recorded within the pools. Barnacles (*Semibalanus balanoides* and *Austromius (Elminius) modestus*) and the keel worm *Spirobranchus* (syn. *Pomatoceros triqueter*) may be attached to shells and small stones. Mobile species typical of rock pool habitats, such as *Crangon crangon* and *Pomatoschistus minutus* will also be found within the pool (JNCC, 2015).

↓ Depth range

Mid shore

🏛️ Additional information

-

✓ Listed By

- none -

🔗 Further information sources

Search on:



Habitat review

🔄 Ecology

Ecological and functional relationships

This biotope is dominated by species able to withstand the frequent disturbance caused by wave action. The fact that LR.H rockpools are shallow and have a mixed substratum means that sand and pebbles will be frequently moved around the rockpool. This is especially true in stormy weather when larger cobbles and boulders may be moved into the pool and when the pool may be flushed clean of sediment. This in itself means that the community is unlikely to be a climax community, but more a transient community dominated by ephemeral, rapidly growing species that are able quickly to dominate space created by wave energy. Furthermore, both the flora and fauna are likely to vary both spatially, i.e. between rock pools, and on a temporal basis, depending on the frequency, severity and timing of disturbance.

- Primary producers in this biotope are represented by ephemeral green algae such as *Ulva* sp. *Ulva intestinalis* can grow rapidly and is tolerant of a range of temperatures and salinities. *Ulva intestinalis* is also the preferred food of *Littorina littorea* (see below).
- In terms of characterizing species, suspension feeders are the dominant trophic group in LR.H. The most common suspension feeders likely to be found in LR.H are the hydroid *Obelia longissima* and the common mussel *Mytilus edulis*. The acorn barnacle *Semibalanus balanoides* may also be common. *Semibalanus balanoides* actively feeds on detritus and zooplankton. *Mytilus edulis* actively feeds on bacteria, phytoplankton, detritus, and dissolved organic matter (DOM). *Obelia longissima* is a passive suspension feeder, feeding on small zooplankton, small crustaceans, oligochaetes, insect larvae and probably detritus. The branches of *Obelia longissima* may be used as substratum by *Mytilus edulis* pediveligers (Brault & Bourget, 1985). Other suspension feeders may include the barnacle *Elminius modestus* and the tubeworm *Spirobranchus triqueter*.
- The grazing gastropod *Littorina littorea* feeds on range of fine red, green and brown algae including *Ulva* sp., *Cladophora* sp. and *Ectocarpus* sp.
- Deposit feeding worms such as the sand mason *Lanice conchilega* and the lugworm *Arenicola marina* may be found if patches of sand are present in the pools. The sand mason is also capable of active suspension feeding.
- The common shore crab *Carcinus maenas* is the largest mobile predator frequently associated with LR.H. *Carcinus maenas* is likely to move in and out of the rockpool feeding on plant and animal material including *Semibalanus balanoides* and *Littorina littorea*.

Seasonal and longer term change

Rockpools constitute a distinct environment for which physiological adaptations by the flora and fauna may be required (Lewis, 1964). Conditions within rockpools are the consequence of prolonged separation from the main body of the sea, and physico-chemical factors within them fluctuate dramatically (Huggett & Griffiths, 1986). Shallow pools such as those associated with LR.H are especially influenced by insolation, air temperature and rainfall, the effects of which become more significant towards the high shore, where pools may be isolated from the sea for a number of days or weeks (Lewis, 1964).

Water temperature in pools follows the temperature of the air more closely than that of the sea. In summer, shallow pools are warmer by day, but may be colder at night, and in winter may be much

colder than the sea (Pyefinch, 1943). It is also possible that shallow pools may freeze over in the coldest winter months.

High air temperatures cause surface evaporation of water from pools, so that salinity steadily increases, especially in pools not flooded by the tide for several days. Alternatively, high rainfall will reduce pool salinity or create a surface layer of brackish/nearly freshwater for a period. The extent of temperature and salinity change is affected by the frequency and time of day at which tidal inundation occurs. If high tide occurs in early morning and evening the diurnal temperature follows that of the air, whilst high water at midday suddenly returns the temperature to that of the sea (Pyefinch, 1943). Heavy rainfall, followed by tidal inundation can cause dramatic fluctuations in salinity, and values ranging from 5-30 psu have been recorded in rockpools over a period of 24 hrs (Ranade, 1957). Rockpools in the supralittoral, littoral fringe and upper eulittoral are liable to gradually changing salinities followed by days of fully marine or fluctuating salinity at times of spring tide (Lewis, 1964).

Due to the frequent disturbances likely to affect this biotope, any seasonal changes are likely to be masked by changes caused by wave energy. Some species of hydroids demonstrate seasonal cycles of growth in spring/summer and regression (die back) in late autumn/winter, overwintering as dormant stages or juvenile stages (Gili & Hughes, 1995). Many hydroids are opportunists adapted to rapid growth and reproduction (r-selected), taking advantage of the spring/summer phytoplankton bloom and more favourable (less stormy) conditions (Gili & Hughes, 1995). Brault & Bourget (1985) noted that *Obelia longissima* exhibited an annual cycle of biomass, measured as colony length, on settlement plates in the St Lawrence estuary. Colony length increased from settlement in June, reaching a maximum in November to March and then decreasing again until June, although the decline late in the year was attributed to predation, and data was only collected over a two year period. The ephemeral algae are also likely to experience an obvious decline in biomass over the winter months.

Habitat structure and complexity

The mixed substratum of the rockpool will give the habitat some heterogeneity since there is likely to be a mixture of sand, gravel, pebbles and cobbles. It is the surfaces of the larger pebbles and cobbles that are likely to be colonized by the algae, barnacles and tubeworms and hydroids although *Obelia longissima* can also grow on coarse clean sand. Clumps of mussels, whether the shells are empty or not, will also provide a substratum for the hydroids and barnacles. The mussel matrix will bind sediment and the sediment trapped between the shells may provide shelter for cryptic species and small worms, for example.

Productivity

No information was found regarding the productivity in LR.H although it is expected to be low. At any given time it is unlikely that there will be a well established community, regardless of species composition.

Recruitment processes

- *Obelia longissima* exhibits a typical leptolid life cycle consisting of a sessile colonial, vegetative hydroid stage, a free-living sexual medusoid stage, and a planula larval stage (see MarLIN review). In terms of reproduction and recruitment, *Obelia longissima* has a number of strategies.
 - *Obelia longissima* can grow vegetatively and branch to form a network across the

substratum. It can also reproduce by fission or mechanical fragmentation of the colony which may aid dispersal (Gili & Hughes, 1995). Hydroids can also form frustules or gemmules, which are thought to be resting stages, in response to stress (Gili & Hughes, 1995). These frustules are adhesive and stick to the substratum where they can form new colonies (Cornelius, 1995a; Kosevich & Marfenin, 1986).

- In terms of sexual reproduction, *Obelia longissima* is dioecious, producing male and female medusae. The medusoid stage lasts between 7 -30 days (Stepanjants, 1998). Eggs and sperm are released into the sea and fertilization is external, resulting in an embryo that develops into a typical planula larva (Cornelius, 1995a, b; Gili & Hughes, 1995). In Europe, the medusae of *Obelia longissima* are usually found in the water somewhere between April and July, depending on area (see *MarLIN* review). Assuming that all the medusae survive to release gametes, Cornelius (1990b) estimated that an average colony could potentially produce about 20,000 planulae, although he also suggested that only one of these planulae was likely to survive to form a colony which itself might survive to reproduce.
- *Ulva intestinalis* is a rapidly growing opportunistic species. It can be found in reproductive condition at all times of the year, but maximum development and reproduction occur during the summer months (Burrows, 1991). The life history consists of an alternation between haploid gametophytic and diploid sporophytic generations (see *MarLIN* review). The haploid gametophytes produce enormous numbers of biflagellate motile gametes which cluster and fuse to produce a sporophyte (diploid zygote). The sporophyte matures and produces large numbers of quadriflagellate zoospores that mature as gametophytes, and the cycle is repeated. Together spores and gametes are termed 'swarmers'. Mobility of swarmers belonging to *Ulva intestinalis* (studied as *Enteromorpha intestinalis*) can be maintained for as long as 8 days (Jones & Babb, 1968) and as a result, tend to have large dispersal shadows. Propagules have been found 35 km from the nearest adult plants (Amsler & Searles, 1980).
- *Littorina littorea* can breed throughout the year but the length and timing of the breeding period are extremely dependent on climatic conditions. Fertilization is internal and *Littorina littorea* sheds egg capsules directly into the sea during spring tides. Eggs are released on several occasions. Fecundity can be as much as 100,000 for a large female (27 mm shell height) per year. Larval settling time or pelagic phase can be up to six weeks.
- Spawning in *Mytilus edulis* is protracted in many populations, with a peak of spawning in spring and summer (see *MarLIN* review). Gametogenesis and spawning varies with geographic location, e.g. southern populations often spawn before more northern populations (Seed & Suchanek, 1992). The planktonic life can exceed two months in the absence of suitable substrata or optimal conditions (Bayne, 1965; Bayne, 1976a). *Mytilus edulis* recruitment is dependant on larval supply and settlement, together with larval and post-settlement mortality. Larval mortality is probably due to adverse environmental conditions, especially temperature, inadequate food supply, 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. Jorgensen (1981) estimated that larvae suffered a daily mortality of 13% in the Isefjord, Denmark but Lutz & Kennish (1992) suggested that larval mortality was approximately 99%. Recruitment in many *Mytilus* sp. populations is sporadic, with unpredictable pulses of recruitment (Seed & Suchanek, 1992). *Mytilus* is highly gregarious and final settlement often occurs around or in-between individual mussels of established

populations.

- *Semibalanus balanoides* is an obligate cross-fertilising hermaphrodite. It produces one brood per year of 5000 -10,000 eggs/ brood in mature adults but this varies with age and location (see *MarLIN* review). Copulation takes place in the UK from November to early December and nauplii larvae are released from the barnacle between February and April, in synchronisation with the spring algal bloom. Nauplii larvae are planktotrophic and develop in the surface waters for about two months. They pass through six nauplii stages before eventually developing into a cyprid larva. Cyprid larvae are specialized for settlement and peak settlement occurs in April to May in the west and May to June in the east and north of Britain although settlement and subsequent recruitment are highly variable.

Time for community to reach maturity

LR.H is subjected to frequent small disturbances and the associated community is characterized by relatively short lived and opportunistic species. As a consequence, the time taken for the community to reach 'maturity' is likely to be fairly rapid, i.e. less than a few years.

- *Obelia longissima* is capable of growing rapidly, budding and forming stolons that allow it to colonize space rapidly. Hydroids are often the first organisms to colonize available space in settlement experiments (Gili & Hughes, 1995). Rapid growth, budding and the formation of stolons allows hydroids to colonize space rapidly. Cornelius (1992) stated that *Obelia longissima* could form large colonies within a matter of weeks.
- *Ulva intestinalis* is opportunistic and capable of rapidly colonizing bare substratum, providing the substratum is suitable. Kitching & Thain (1983), for example, reported that following the removal of the urchin *Paracentrotus lividus* (that grazes on the *Ulva* sp.) from areas of Lough Hyne, Ireland, *Ulva* sp. grew over the cleared area and reached a coverage of 100% within one year.
- *Littorina littorea* is a slow crawler but because LR.H rockpools are likely to be surrounded by other rockpools, active immigration of snails is possible from the surrounding rocky shore where *Littorina littorea* may be abundant.
- The establishment of the *Mytilus edulis* community may take significantly longer (see Sensitivity). However, this species is not characteristic of the biotope. Furthermore, if *Mytilus edulis* are present in LR.H, they will usually be part of a larger mussel bed (SLR.MytX) and this will favour recruitment to the area. Recovery of *Mytilus edulis* may take at least 5 years, although in certain circumstances and under some environmental conditions recovery may take significantly longer.
- Bennell (1981) observed that barnacles were removed when the surface rock was scraped off in a barge accident at Amlwch, North Wales. Barnacle populations returned to pre-accident levels within 3 years. However, barnacle settlement and recruitment can be highly variable because they are dependent on a suite of environmental and biological factors (see *MarLIN* review), therefore populations may take longer to recover.

Additional information

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Preferences & Distribution

Habitat preferences

Depth Range	Mid shore
Water clarity preferences	
Limiting Nutrients	Data deficient
Salinity preferences	Full (30-40 psu)
Physiographic preferences	Enclosed coast / Embayment
Biological zone preferences	Eulittoral
Substratum/habitat preferences	Cobbles, Pebbles, Gravel / shingle, Sand
Tidal strength preferences	
Wave exposure preferences	Moderately exposed, Sheltered
Other preferences	Enclosed coasts (inlets, harbours)

Additional Information

LR.H is found in moderately exposed to sheltered habitats. It is considered rare (Connor *et al.*, 1997b).

Species composition

Species found especially in this biotope

Rare or scarce species associated with this biotope

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Additional information

The MNCR reported 129 species from this biotope, although not all species occur in all examples of the biotope (JNCC, 1999).

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The biotope description and characterizing species are taken from Connor *et al.* (2004). This biotope is described as shallow pools on mixed cobbles, pebbles, gravel and sand that are characterized by abundant hydroids. Species present may include *Obelia geniculata*, *Obelia dichotoma*, *Obelia longissima*, *Sertularia cupressina*, *Tubularia indivisa* and *Thuiaria thuja*. The difficulty in identifying hydroids suggests many more species may be present. A wide range of other species are typically found in this biotope; these include the ephemeral green algae (*Enteromorpha* spp. and *Ulva* sp.), red algae (*Chondrus crispus* and Coralline algae) and the winkle *Littorina littorea*. The genus *Ulva* currently contains 23 taxonomically accepted species (Guiry & Guiry, 2015), although the genus is now more generally accepted as a synonym for *Ulva* (Hayden *et al.*, 2003). Within the pools, patches of sand may be occupied by the lugworm *Arenicola marina* and sand mason worms *Lanice conchilega*. These pools are often associated with mussel beds (MytX), with *Mytilus edulis* frequently recorded within the pools. Barnacles (*Semibalanus balanoides* and *Elminius modestus*) and the keel worm *Spirobranchus triqueter* may be attached to shells and small stones. Mobile species typical of rock pool habitats, such as *Crangon crangon* and *Pomatoschistus minutus* will also be found within the pool.

Little information was found for this biotope and there are few records. The sensitivity assessments specifically consider the key characterizing hydroids, ephemeral algae (*Ulva* sp.) and winkle *Littorina littorea* that are named in the biotope title. Due to the range of hydroid species present most assessments for this group are quite general. The presence of hard substrata and sediment patches within this biotope provide suitable habitat for attached and burrowing species respectively and the sensitivity of these species is considered generally. As these pools are associated with mussel beds (Connor *et al.*, 2004) the sensitivity of mussel beds is presented for pressures that have been identified as altering the *Mytilus edulis* beds as these may alter the habitat and hence this biotope. The important factors structuring and maintaining this biotope are the presence of water and the mixed substrata, changes to these would alter the biotope and these factors are considered in assessments where the pressure may alter these. Wave action, the presence of sand deposits and/or the mobility of mixed substrata and the abrasion that results when sediments are shifted by wave and water flows maintains this community by preventing succession to a fucoid community. These factors are considered within the sensitivity assessments where they may be altered by the pressure.

Resilience and recovery rates of habitat

This biotope is subject to the normal environmental fluctuations of salinity, temperature and desiccation experienced by intertidal pools. Wave action, sediment mobility and abrasion maintains these pools in an early successional stage, characterized by species that can either tolerate disturbance and environmental stress or opportunist species that can recolonize rapidly. The characterizing hydroids and ephemeral algae species and the species associated with this biotope are therefore considered to generally have high rates of resilience (recovery). Due to the frequent disturbances likely to affect this biotope, seasonal changes are likely to be masked by changes caused by wave energy. Some species of hydroids, including *Obelia longissima* a species found in this biotope, demonstrate seasonal cycles of growth in spring/summer and regression (die back) in late autumn/winter, overwintering as dormant stages or juvenile stages (Gili & Hughes, 1995; Brault & Bourget, 1985). Similarly the ephemeral algae may experience die-back over an annual cycle and the mobile grazing *Littorina littorea* may become more dominant. Other species

found within the biotope such as *Spirobranchus* (formerly *Pomatoceros*) *triqueter* are typical of disturbed biotopes and recover annually (Tillin & Tyler-Walters, 2014, references therein) or are highly mobile, such as *Crangon crangon* and *Pomatoschistus* sp., and will return to disturbed pools.

Hydroids exhibit rapid rates of recovery from disturbance through repair, asexual reproduction and larval colonization. Fragmentation of the hydroid provides a route for short distance dispersal, for example, each fragmented part of *Sertularia cupressina* can regenerate itself following damage (Berghahn and Offermann, 1999). New colonies of the same genotype may therefore arise through damage to existing colonies (Gili & Hughes, 1995). Many hydroid species also produce dormant, resting stages that are very resistant of environmental perturbation (Gili & Hughes 1995). Although colonies may be removed or destroyed, the resting stages may survive attached to the substratum and provide a mechanism for rapid recovery (Cornelius, 1995a; Kosevich & Marfenin, 1986). The lifecycle of hydroids typically alternates between an attached solitary or colonial polyp generation and a free-swimming medusa generation. Planulae larvae produced by hydroids typically metamorphose within 24 hours and crawl only a short distance away from the parent plant (Somer, 1992). Gametes liberated from the medusae (or a vestigial sessile medusae) produce gametes which fuse to form zygotes that develop into free-swimming planula larvae (Hayward & Ryland, 1994) that are present in the water column between 2-20 days (Somer, 1992). It has also been suggested that rafting on floating debris as dormant stages or reproductive adults (or on ships hulls or in ship ballast water), together with their potentially long lifespan, may have allowed hydroids to disperse over a wide area in the long-term and explain the near cosmopolitan distributions of many hydroid species (Cornelius, 1992; Boero & Bouillon 1993). Due to these biological characteristics hydroids are fouling organisms, rapidly colonising a range of substrata placed in marine environments and are often the first organisms to colonize available space in settlement experiments (Gili & Hughes, 1995). For example, hydroids were reported to colonize an experimental artificial reef within less than 6 months becoming abundant in the following year (Jensen *et al.*, 1994). In similar studies, *Obelia* species recruited to the bases of reef slabs within three months and the slab surfaces within six months of the slabs being placed in the marine environment (Hatcher, 1998). Cornelius (1992) stated that *Obelia longissima* could form large colonies within a matter of weeks. In a study of the long-term effects of scallop dredging in the Irish Sea, Bradshaw *et al.*, (2002) noted that hydroids increased in abundance, presumably because of their regeneration potential, good local recruitment and ability to colonize newly exposed substratum quickly.

The *Ulva* sp. that characterize this biotope are also classified as opportunistic species that are able to rapidly colonize newly created gaps across a range of sediment types, shore heights, wave exposures and salinity regimes. The life history characteristics that support this opportunism are the broad tolerances for a wide range of conditions (Vermaat & Sand-Jensen, 1987) and high growth and reproduction rates. *Ulva* sp. release zoospores and gametes (collectively called swimmers) to the water column in high numbers. *Ulva* sp. can form the swimmers from normal thallus cells that are transformed into reproductive tissue rather than having to produce specialised reproductive structures (Lersten & Voth, 1960), so that a significant portion of the macroalga's biomass is allocated to the formation of zoospores and gametes (Niesenbaum, 1988). *Ulva* sp. have extended reproduction periods (Smith, 1947) and swimmers are capable of dispersal over a considerable distance. For instance, Amsler & Searles (1980) showed that swimmers of a coastal population of *Ulva* (as *Enteromorpha*) reached exposed artificial substrata on a submarine plateau 35 km away.

The supply of swimmers in vast numbers to the coastline (Niesenbaum, 1988) is reflected in the fast recovery rates of this genus. *Ulva intestinalis* is amongst the first multicellular algae to appear

on substrata that have been cleared following a disturbance, e.g. following the Torrey Canyon oil spill in March 1967, species of the genus *Ulva* rapidly recruited to areas where oil had killed the herbivores that usually grazed on them, so that a rapid greening of the rocks (owing to a thick coating of *Ulva* spp.) was apparent by mid-May (Smith, 1968). The rapid recruitment of *Ulva* spp. to areas cleared of herbivorous grazers was also demonstrated by Kitching & Thain (1983). Following the removal of the urchin *Paracentrotus lividus* from areas of Lough Hyne, Ireland, *Ulva* grew over the cleared area and reached a coverage of 100% within one year.

Other species that are associated with this biotope, the barnacle *Semibalanus balanoides* and littorinids generally have slower recovery rates than hydroids and *Ulva* spp. due to episodic recruitment and slower growth, although resilience is still assessed as 'High' (within 2 years) across all levels of resistance. The barnacles and the winkle *Littorina littorea* are common, widespread species that spawn annually producing pelagic larvae that can disperse over long distances. It is therefore likely that adjacent populations will provide high numbers of larvae, although recruitment may be lowered due to habitat unsuitability and the presence of dense hydroid and *Ulva* spp. preventing settlement on rock surfaces. Where individuals are removed from a small area, adult *Littorina littorea* may recolonize from surrounding patches of habitat where these are present. *Littorina littorea* are specifically considered within the resilience assessments as these are a key characterizing and structuring species. As littorinids graze on the macroalgae characterizing the biotope they can prevent blooms of *Ulva* spp. forming (Robles, 1982, Albrecht, 1998), changes in their abundance would therefore alter the character of the biotope.

Mainwaring *et al.* (2014) reviewed the evidence for recovery of *Mytilus edulis* beds from disturbance and an earlier study by Seed & Suchanek (1992) reviewed studies on the recovery of 'gaps' in *Mytilus* spp. beds. Based on life history traits and patterns in recruitment this species is likely to be the slowest to recover within this biotope. 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. Recruitment of *Mytilus edulis* is often sporadic, occurring in unpredictable pulses (Seed & Suchanek, 1992), although persistent mussel beds can be maintained by relatively low levels or episodic recruitment (McGrorty *et al.*, 1990). A good annual recruitment could result in rapid recovery (Holt *et al.*, 1998). However, the unpredictable pattern of recruitment based on environmental conditions could result in recruitment taking much longer. In the northern Wadden Sea, strong year classes (resulting from a good recruitment episode) that lead to rejuvenation of blue mussel beds are rare, and usually follow severe winters, even though mussel spawning and settlement are extended and occur throughout the year (Diederich, 2005). In the List tidal basin (northern Wadden Sea) a mass recruitment of mussels occurred in 1996 but had not been repeated by 2003 (the date of the study), i.e. for seven years (Diederich, 2005).

Resilience assessment. The hydroids and ephemeral algae that characterize this biotope are likely to recover from damage very quickly. Based on the available evidence resilience is assessed as 'High' (recovery within two years) for any level of perturbation (where resistance is 'None', 'Low', 'Medium' or 'High'. Depending on the season of the impact and level of recovery, the biotope may have recovered within less than six months. It should be noted that this biotope is maintained by chronic disturbances such as wave action, sediment mobility and sand scour, that prevent a typical succession process occurring: recovery rates will therefore depend on the recovery of the disturbance regime. Recovery of the ephemeral algae may also be prevented where large numbers of grazers become established, this will again depend on changes in the key environmental factors maintaining the biotope. Where changes would permanently favour grazers recovery would be judged as 'Very Low'. It should be noted however that some changes in abundance of grazers and

algae may be cyclical and part of normal temporal fluctuation within the biotope. The age structure of populations of the associated species, such as those in the sand patches that may be removed annually is likely to be skewed towards young individuals due to high levels of mortality from disturbances. Biotope recovery to the normal state is considered to be rapid and resilience is assessed as 'High' (within 2 years) for all levels of resistance (None, Low, Medium and High).

This biotope may occur within beds of *Mytilus edulis* (Connor *et al.*, 2004). The resilience of *Mytilus edulis* within this biotope and the resilience of adjacent beds is not specifically included in the sensitivity assessment but is noted here. Where the bed itself is important for stabilising substratum and allowing this biotope to exist then the creation of gaps in adjacent beds or their loss may remove this biotope and its recovery will be longer, as indicated. Overall, *Mytilus* spp. populations are considered to have a strong ability to recover from environmental disturbance (Holt *et al.*, 1998; Seed & Suchanek, 1992) and a good annual recruitment may allow a bed to recover rapidly, though this cannot always be guaranteed within a certain time-scale due to the episodic nature of *Mytilus edulis* recruitment (Lutz & Kennish, 1992; Seed & Suchanek, 1992) and the influence of site-specific variables. Resilience will vary depending of larval supply and wave exposure with areas with low larval supply and high wave exposure on sandy substrata experiencing the longest recovery rates. Mainwaring *et al.* (2014) suggested that littoral beds are considered to have 'Medium' resilience (2 - 10 years) to represent the potential for recovery within a few years where a proportion of the bed remains ('Medium' or 'Low' resistance). Resilience is assessed as 'Low' (over 10 years) for all biotopes where resistance is assessed as 'None', as recovery is dependent on recruitment from other areas and recruitment can be sporadic.

NB: The resilience and the ability to recover from human induced pressures is a combination of the environmental conditions of the site, the frequency (repeated disturbances versus a one-off event) and the intensity of the disturbance. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval-supply and recruitment between populations. Full recovery is defined as the return to the state of the habitat that existed prior to impact. This does not necessarily mean that every component species has returned to its prior condition, abundance or extent but that the relevant functional components are present and the habitat is structurally and functionally recognisable as the initial habitat of interest. It should be noted that the recovery rates are only indicative of the recovery potential.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	Medium Q: High A: Medium C: High	High Q: High A: Low C: High	Low Q: High A: Low C: High

As the biotope LR.FLR.H is found in shallow eulittoral rockpools, the associated community must be adapted, to a certain degree, to frequent and often rapid changes in temperature. Air temperatures can be greatly elevated on hot days and due to the shallow nature of the pool, the water is likely to heat up quickly.

The key characterizing *Ulva* spp. are distributed globally and occur in warmer waters than those surrounding the UK suggesting that they can withstand increases in temperature at the pressure benchmark. *Ulva* spp. are characteristic of upper shore rock pools, where water and air temperatures are greatly elevated on hot days. Empirical evidence for thermal tolerance to

anthropogenic increases in temperature is provided by the effects of heated effluents on rocky shore communities in Maine, USA. *Ascophyllum* and *Fucus* were eliminated from a rocky shores heated to 27-30°C by a power station whilst *Ulva intestinalis* (as *Enteromorpha intestinalis*) increased significantly near the outfall (Vadas *et al.*, 1976). The median upper lethal temperature limit in laboratory tests on the characterizing species *Littorina littorea* and the associated species *Semibalanus balanoides* was approximately 35°C (Davenport & Davenport, 2005).

In a review of the ecology of hydroids, Gili & Hughes, (1995) report that temperature is a critical factor stimulating or preventing reproduction and that most species have an optimal temperature for reproduction. However, limited evidence for thermal thresholds and thermal ranges were available for the typical species recorded in this biotope. Stepanjants (1998) regarded *Obelia longissima* as a cold water species, with a bipolar distribution, while other authors regarded this species as probably cosmopolitan in distribution (Boero & Bouillon, 1993; Cornelius, 1995). Cornelius (1995) suggested that numerous records in the Indo-Pacific were probably attributable to *Obelia longissima*. Berrill (1949) reported that growth in *Obelia commissularis* (syn. *longissima*) was temperature dependent but ceased at 27°C. Hydranths did not start to develop unless the temperature was less than 20°C and any hydranths under development would complete their development and rapidly regress at ca 25°C. Berrill (1948) reported that *Obelia* species were absent from a buoy in July and August during excessively high summer temperatures in Booth Bay Harbour, Maine, USA. Berrill (1948) reported that the abundance *Obelia* species and other hydroids fluctuated greatly, disappearing and reappearing as temperatures rose and fell markedly above and below 20°C during this period. The upwelling of cold water (8-10°C colder than surface water) allowed colonies of *Obelia* sp. to form in large numbers. Berrill (1948) suggested that *Obelia longissima* grew vigorously in warm weather, although at temperatures above 20°C, growth of terminal stolons and branches was promoted but the formation of hydranths inhibited. Therefore, it would appear that *Obelia longissima* is intolerant of acute temperature changes above 20°C. *Sertularia argentea* is found in the North Sea, Bay of Fundy and France.

Laboratory studies suggest that adult *Littorina littorea* and *Semibalanus balanoides* can tolerate temperature increases. The median upper lethal temperature limit in laboratory tests on *Littorina littorea* and *Semibalanus balanoides* was approximately 35 °C (Davenport & Davenport). Although adults may be able to withstand acute and chronic increases in temperature at the pressure benchmark, increased temperatures may have sub-lethal effects on the population by impacting the success of reproduction phases. Populations of *Semibalanus balanoides* in the southern part of England are relatively close to the southern edge of their geographic range and temperatures above 10 to 12 °C inhibit reproduction in *Semibalanus balanoides* (Barnes, 1957 & 1963; Crisp & Patel, 1969; Rognstad *et al.*, 2014; Jenkins *et al.*, 2000). Increased temperatures are likely to lead to replacement by the warm water species *Chthamalus montagui* and *Chthamalus stellatus* (Southward *et al.*, 1995) although this would not significantly affect the character of the biotope. The blue mussel *Mytilus edulis* is found within the biotope and the biotope may occur within *Mytilus edulis* beds. *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 recent years, *Mytilus edulis* has been observed to be expanding its range pole-wards and has reappeared in Svalbard, due to an increase of sea temperature in that region (Berge *et al.*, 2005), whilst its equatorial limits are contracting due to increases in water temperature beyond the lethal limit (Jones *et al.*, 2010). 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). 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, the heat shock proteins were still present over 14 days later, although at a reduced level. In

shallow lagoons mortality began in late July at the end of a major spawning event when temperatures peaked at $>20^{\circ}\text{C}$. 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).

Sensitivity assessment. Hydroids may be the most sensitive element of the biotope to changes in temperature, and temperature and desiccation may restrict this biotope to the mid-shore. It is likely that *Obelia longissima* is highly intolerant to an acute rise in temperature at the benchmark level since temperatures in excess of 20°C can reasonably be expected over summer in a shallow eulittoral rockpool. As Berrill (1948) suggested, other hydroids may be equally intolerant. An acute or chronic change in temperature resulting in unfavourable conditions may result in regression to a dormant resting change, with growth resuming when conditions are more suitable. Resistance is therefore assessed as 'Medium'. *Littorina littorea* and *Ulva* spp., as key characterizing species are considered to tolerate increases in temperature (acute and chronic) at the pressure benchmark. Biotope resistance is therefore assessed as 'Medium' (based on the sensitivity of hydroids, and recovery as 'High' so that biotope sensitivity to an acute change is assessed as 'Low'. 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 benchmarks of $2-5^{\circ}\text{C}$ would have limited effect and intertidal *Mytilus edulis* beds are also considered to be 'Not sensitive'. The timing of acute increases would alter the degree of impact and hence sensitivity. An acute change occurring on the hottest day of the year and exceeding thermal tolerances could lead to mortality in species that would otherwise withstand the pressure.

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

Due to the fact that LR.H is found in shallow eulittoral rockpools, the associated community must be adapted, to a certain degree, to frequent and often rapid changes in temperature as they are exposed to extremes of low air temperatures during periods of emersion which lead to temperature fluctuations in shallow pools. In winter, air temperatures are colder than the sea and these pools may even freeze over during the coldest winter months.

The key species characterizing this biotope, *Ulva intestinalis* and *Ulva lactuca*, are found in Arctic regions (Guiry & Guiry, 2015 and references therein), *Ulva* sp. (as *Enteromorpha*) were reported to be tolerant of a temperature of -20°C (Kylin, 1917). Vermaat & Sand-Jensen (1987) found that rapid deep freezing of *Ulva lactuca* collected in Roskilde Fjord, Denmark killed the plants. However, individuals from the same area when collected from frozen ice, survived and resumed growth, the plants are able to survive more gradual natural freezing (Vermaat & Sand-Jensen, 1987). The key characterizing species *Littorina littorea* are also tolerant of low temperatures. In experiments *Littorina littorea* were able to tolerate temperatures down to -8°C for 8 days (Murphy, 1983). In colder conditions an active migration may occur down the shore to a zone where exposure time to the air (and hence time in freezing temperatures) is less. The tolerance of *Littorina littorea* collected in the winter from Great Cumbrae (and thus acclimated to lower temperatures) to low temperatures was tested in the laboratory. The median lower lethal temperature tolerance of *Littorinas littorea* was -13°C (Davenport & Davenport, 2005). The same series of experiments indicated that median lower lethal temperature tolerances for *Semibalanus balanoides* was -14.6°C . The distribution of *Semibalanus balanoides* is 'northern' with their range extending to the Arctic circle. Over their range they are therefore subject to lower temperatures

than in the UK, although distributions should be used cautiously as an indicator of thermal tolerance (Southward *et al.*, 1995). Long-term time series show that recruitment success is correlated to lower sea temperatures (Mieszkowska *et al.*, 2014). Experiments show that acclimation to lower temperatures alters tolerances. In *Semibalanus balanoides* cold tolerance is greater in December and January and lower in warmer months. The median lethal temperature in January was -17.6°C in air for 18 hours, whereas animals in June could only withstand -6.0°C (Crisp & Ritz, 1967). *Semibalanus balanoides* was not affected during the severe winter of 1962-63 in most areas, except the south east coast which suffered 20-100 % mortality (Crisp, 1964).

Less evidence was found for thermal tolerances of hydroids. Kosevich & Marfenin (1986) reported that *Obelia longissima* was active all year round in the White Sea. Similarly, its northern limit lies in the Arctic Circle (Cornelius, 1995b; Stepanjants, 1998) suggesting that it probably tolerant of the lowest temperatures it is likely to encounter in Britain and Ireland. However, growth rates are reduced at low temperatures. Berrill (1949) reported that stolons grew, under optimal nutritive conditions, at less than 1 mm in 24 hrs at $10-12^{\circ}\text{C}$, 10 mm in 24 hrs at $16-17^{\circ}\text{C}$, and as much as 15-20 mm in 24 hrs at 20°C .

Mytilus edulis can also withstand extreme cold and freezing, surviving when its tissue temperature drops to -10°C (Williams, 1970; Seed & Suchanek, 1992) or exposed to -30°C for as long as six hours twice a day (Loomis, 1995). Bourget (1983) reported that cyclic exposure to otherwise sublethal temperatures, e.g. -8°C every 12.4 hrs resulted in significant damage and death after 3-4 cycles. During the cold winter of 1962/63, *Mytilus edulis* was reported to have experienced relatively few effects with only 30 % mortality being recorded from the south east coast of England (Whitstable area) and only about 2 % mortality was reported from Rhosilli in South Wales (Crisp, 1964). Crisp (1964) also noted that the mortality was mainly from predation on the individuals that were weakened by the low temperatures rather than the temperature itself. It is thought that the use of nucleating agents in the haemolymph and the maintenance of a high osmotic concentration in the mantle fluid during periods of winter isolation allows *Mytilus edulis* to tolerate such low temperatures (Aunaas *et al.*, 1988). This suggests that *Mytilus edulis* can survive occasional, sharp frost events, but may succumb to consistent very low temperatures over a few days. Although *Mytilus edulis* may be intolerant of prolonged freezing temperatures, it is generally considered to be eurythermal.

Sensitivity assessment. The presence of *Ulva* spp. in arctic regions and the freezing tolerances reported by Vermaat & Sand-Jensen (1987) indicate that *Ulva* spp., would have 'High' resistance to decreases in temperature at the acute and chronic benchmarks. although evidence is limited, the hydroids are also considered to be tolerant of decreases in temperature at the pressure benchmark. The wide temperature tolerance range of *Littorina littorea* suggest that the acute and chronic decreases in temperature described by the benchmark would not lead to mortalities. Similarly, based on global temperatures and the link between cooler winter temperatures and reproductive success, the associated species, *Semibalanus balanoides* and *Mytilus edulis* are also considered to be unaffected at the pressure benchmark. Based on the characterizing and associated 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'. The timing of changes and seasonal weather could result in greater impacts on species. An acute decrease in temperature coinciding with unusually low winter temperatures may exceed thermal tolerances and lead to mortalities of the associated species although this would not alter the character of the biotope.

Salinity increase (local)

High

Q: Low A: Low C: Low

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

This biotope is recorded in full salinity habitats (Connor *et al.*, 2004). High air temperatures cause surface evaporation of water from pools, so that salinity steadily increases. The extent of temperature and salinity change is affected by the frequency and time of day at which tidal inundation occurs. If high tide occurs in the early morning and evening, the diurnal temperature follows that of the air, whilst high water at midday suddenly returns the temperature to that of the sea (Pyefinch, 1943). Heavy rainfall, followed by tidal inundation can cause dramatic fluctuations in salinity, and values ranging from 5-30 psu have been recorded in rockpools over a period of 24 hrs (Ranade, 1957). As a consequence of such a regime, the entire LR.FLR.H community will be adapted, to a certain degree, to fluctuating salinities. It should be noted however that 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.

Studies on hydroids in general have found that prey capture rates may be affected by salinity and temperature (Gili & Hughes, 1995) although no evidence was found for species that characterize this biotope. *Ulva* species are tolerant of extreme salinities ranging from 0 psu to 136 psu (Reed & Russell, 1979). Some variations in salinity tolerance between populations of *Ulva intestinalis* have been found, however, suggesting that plants have some adaptation to the local salinity regime. Reed & Russell (1979) found that the ability to regenerate from cut thalli varied according to the salinity conditions of the original habitat, and that the pattern of euryhalinity in parental material and offspring was in broad agreement (Reed & Russell (1979). Eulittoral zone material showed decreased percentage regeneration in concentrated seawater: 51, 68, 95, 102 & 136 psu) when compared to littoral fringe populations of *Ulva intestinalis* (as *Enteromorpha intestinalis*). Increased salinity is most likely to occur in the region of the littoral fringe and supralittoral zone and specimens from these areas were able to tolerate very high salinities, a significant decrease in regeneration only being recorded after exposure to concentrated seawater (102 psu and 136 psu) for > 7 days (Reed & Russell, 1979).

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. The blue mussel *Mytilus edulis* is frequently found in this biotope, 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.

Sensitivity assessment. The characterizing hydroid and *Ulva* species and the associated species are considered able to tolerate increases in salinity. Based on reported distributions and the results of experiments to assess salinity tolerance thresholds and behavioural and physiological responses it is considered that *Ulva* spp. and the associated littorinids and barnacles would tolerate a change in salinity from variable or reduced to full and some salinity increases above full salinity. As the associated species occur only in low numbers and do not characterize the biotope the sensitivity assessment is based on the *Ulva* species alone. Biotope resistance is assessed as 'High' and resilience as 'High', based on no effect to recover from and the biotope is considered to be 'Not sensitive'. It should be noted that no evidence was found to assess the sensitivity of hydroids and confidence in the resistance assessment is therefore assessed as 'Low'.

Salinity decrease (local)

High

Q: High A: High C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: High C: High

This biotope is recorded in full salinity habitats (Connor *et al.*, 2004). However, high rainfall will

reduce salinity in rock pools when exposed to air and may create a surface layer of brackish/nearly freshwater for a period. Heavy rainfall, followed by tidal inundation can cause dramatic fluctuations in salinity, and values ranging from 5-30 psu have been recorded in rockpools over a period of 24 hrs (Ranade, 1957). As a consequence of such a regime, the entire LR.H community will be adapted, to a certain degree, to fluctuating salinities.

The key characterizing *Ulva* spp. and littorinids are euryhalina species, found in a range of salinities and are therefore considered to tolerate changes in salinity at the pressure benchmark (a change from full salinity to reduced). *Littorina littorea* is found in waters of full, variable and reduced salinities (Connor *et al.*, 2004) and are considered to be unaffected by a decrease in salinity at the pressure benchmark. Similarly, *Ulva intestinalis* is a euryhaline species, tolerant of extreme salinities ranging from 0 psu to 136 psu (Reed & Russell, 1979). Although prolonged, reduced salinity can affect the growth rate of *Ulva intestinalis* (Martins *et al.*, 1999). *Obelia longissima* are also found in areas of reduced salinity.

Evidence on salinity tolerances was also found for the associated species that occur in this biotope. The barnacle *Semibalanus balanoides* is tolerant of a wide range of salinity and can survive periodic emersion in freshwater, e.g. from rainfall or freshwater runoff, 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" and can be found on shores (example from Sweden) with large fluctuations in salinity around a mean of 24 (Jenkins *et al.*, 2001). In areas of permanently reduced salinity the Australian barnacle *Austrominius* (formerly *Elminius*) *modestus* may be favoured, as this species is more tolerant of lower salinities, although this is balanced against its lower tolerance of wave exposure. The blue mussel *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 percent of control animals within one month. *Mytilus edulis* can also survive considerably reduced salinities, growing as dwarf individuals at 4-5 psu in the Baltic. Extreme reductions in salinity may however kill individuals acclimated to higher salinities, for example, following storm runoff, large numbers of mussels may be killed (Keith Hiscock, pers comm.)

Sensitivity assessment. The characterizing hydroids, *Littorina littorea* and *Ulva* species and the associated *Mytilus edulis* and *Semibalanus balanoides* are considered able to tolerate a change from full to variable salinity. Biotope 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: Low A: NR C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

As the biotope is found in shallow eulittoral rock pools water flows are not significant during periods of emergence although wind driven water movement may occur. Wave driven water action can vary as this biotope occurs from moderately exposed to sheltered conditions (Connor *et al.*, 2004).

The key characterizing hydroids are typically found in places of moderate water movement although Hayward & Ryland (1995) note that the abundant communities occur in narrow straits and headlands which may experience high levels of water flow. Hydroids can bend passively with water flow to reduce drag forces to prevent detachment and enhance feeding (Gili & Hughes, 1995). Hydroid growth form also varies to adapt to prevailing conditions, allowing species to occur in a variety of habitats (Gili & Hughes, 1995). Hiscock, (1979) assessed feeding behaviour

of the hydroid *Tubularia indivisa* (one of the hydroids typically found in this biotope) in response to different flow rates. At flow rates <0.05 m/s polyps actively moved tentacles, increasing the flow rate to 0.2 m/s increased capture rates but at higher flow rates from 0.5-0.9 m/s the tentacles were extended downcurrent and pushed together and feeding efficiency was reduced. In general, flow rates are an important factor for feeding in hydroids and prey capture appears to be higher in more turbulent conditions that prevent self-shading by the colony (Gili & Hughes, 1995). The capture rate of zooplankton by hydroids is correlated with prey abundance (Gili & Hughes, 1995), thus prey availability can compensate for sub-optimal flow rates. Water movements are also important to hydroids to prevent siltation which can cause death (Round, 1961). Tillin & Tyler-Walters (2014) suggest that the range of flow speeds experienced by biotopes in which hydroids are found indicate that a change (increase or decrease) in the maximum water flow experienced by mid-range populations for the short periods of peak spring tide flow would not have negative effects on this ecological group. Other attached filter-feeding species found in the biotope such as barnacles, mussels *Mytilus edulis* and *Spirobranchus triqueter* (formerly *Pomatoceros triqueter*) are found in a range of water flows and are not considered to be impacted by changes in water flow at the benchmark level. 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 key characterizing species *Littorina littorea* is found in areas with water flow rates from negligible to strong, although populations exposed to different levels of flow may have adapted to local conditions. Increases in water flow rates above 6 knots (3 m/s) may cause individuals in less protected locations (e.g. not in crevices etc.) to be continually displaced into unsuitable habitat so that feeding may become sub-optimal. Shell morphology within littorinids varies according to environmental conditions; in sheltered areas shell apertures are small to inhibit predation where *Carcinus maenas* is more prevalent. In exposed areas the foot surface is larger to allow greater attachment and the shell spire is lower to reduce drag (Raffaelli 1982, Crothers, 1992). In sites with mobile cobbles and boulders increased scour results in lower densities of *Littorina* spp. compared with other, local sites with stable substratum (Carlson *et al.*, 2006).

The key characterizing *Ulva* spp. also occurs in a range of flow strengths. Kennison & Fong (2013) found that *Ulva intestinalis*, settled on ceramic tiles and deployed in the field were subject to greater losses at mean flow speeds of 0.2 m/s (approximately 16% of biomass) than the 8% loss from individuals subject to lower flows (0.15 m/s). These results agree with those from another study by Flindt *et al.* (2007) that subjected *Ulva* sp. and *Enteromorpha* sp. to increased water flows in flume tanks. Water flow rates were increased from still water incrementally by 0.005 m/s and the amount of biomass sloughed off was measured. At a current speed of 0.12 m/s 3-4 % of biomass of *Ulva* sp. was removed, increasing to 4-7 % lost at 0.15 m/s and 40-50 % at 0.4 m/s. *Enteromorpha* sp. were slightly more resistant; at current flows of 0.2 m/s 1 % of biomass was sloughed, increasing to 20 % at 0.35 m/s. Flindt *et al.* (2007) estimated from regression models that the current speeds at which all *Ulva* spp., would be totally removed were 0.82 m/s and 1.28 m/s for *Enteromorpha* sp. Modelled predictions of thallus breakage based on laboratory studies of *Ulva lactuca* on bivalve shells estimate that large *Ulva lactuca* (>50 cm in length) are unlikely to persist where currents exceed 0.5 m/s, whereas smaller individuals (24 cm in length) are unlikely to be present where current speeds exceed 1 m/s (Hawes & Smith, 1995). Increased water flows may also be beneficial to *Ulva* spp. where these enhance recruitment. Increased water velocities can enhance recruitment through increased larval supply (Kennison & Fong, 2013). Houghton *et al.* (1973) observed that swimmers of *Ulva* were able to settle onto surfaces subjected to water speeds of up to 10.7 knots, suggesting that changes may not inhibit settlement.

Blue mussel bed biotopes which may be associated with this biotope are recorded from week (<0.5 m/s) to strong (up to 3 m/s) tidal streams. The sensitivity of sedimentary biotopes to increased flow is dependent on the substratum and the degree of cover, with dense beds of ca 100 % cover being more stable than patchy beds, and more stable on mixed substrata with cobble and boulders than sand and mud. Connor *et al.* (2004) noted that the build-up of mussel mud beneath beds could result in a change from sandy to muddy substrata underneath the bed, and reduce attachment resulting in increased risk of removal by storms. A decrease in water flow is unlikely to affect adversely blue mussel beds directly. Evidence suggests that they can grow at water flow rates as low as 0.01 – 0.02 m/s (Langan & Howell, 1994) and filter at 0.05 m/s (Widdows *et al.*, 2002). At very low or negligible water flow, the effects of siltation may have adverse effects (see relevant pressure). Dense beds are probably stable on mixed substrata, so resistance to change in water flow is probably 'High', resilience is assessed as 'High' (no effect to recover from) and the biotope is assessed as 'Not Sensitive' (Mainwaring *et al.*, 2014).

Changes in water flow at the pressure benchmark, experienced during immersion, may however lead to significant changes in the physical structure of this biotope by removing the finer fractions of the mixed sediment and perhaps resulting in greater mobility of larger pebbles and cobbles increasing abrasion and scour. Changes greater than the pressure benchmark may mobilise pebbles, cobbles and boulders and may remove the habitat. Alternatively, decreases in flow may result in greater deposition. Where changes in sediment result in loss of tide pools and attachment surfaces the character of this biotope would significantly change. An increase or decrease in flow may also result in a change in suspended solids (see relevant pressure). An increase or decrease in flow, that results in sediment removal with less, or no, sand being deposited within the pools due to a lack of re-suspension from source sediments or velocities too high to allow sand to settle, would lead to a reduction in species richness through the loss of the species associated with the sediments but would not alter the classification of this biotope. Conversely a decrease in water flow that allowed silt to accumulate and settle on surfaces may have negative impacts on settlement and recruitment of the key characterizing *Ulva* spp. and hydroids as well as reducing habitat suitability for other associated species that attach to the hard surfaces (see siltation pressure assessments). Sediment transport processes are influenced by a range of site-specific factors including local sediment supply and topography. A generic assessment is not possible and this indirect effect is not assessed for this pressure, although the siltation and changes in sediment type pressures indicate sensitivity to habitat changes. It should be noted also that wave action may be a more important factor for sediment transport in this biotope than local tidal currents.

Sensitivity assessment. LR.FLR.H is found in shallow eulittoral rock pools and is not expected to experience any water flow, unless they are covered by the tide, apart from wind driven water movement. Hydroids can feed in a range of flow rates and the key characterizing *Ulva* spp., hydroids and *Littorina littorea* have been recorded from a range of water flow velocities. Increased water flow rates may detach and remove biomass of the *Ulva* spp, that characterize this biotope. Experiments suggest that the pressure benchmark is biologically relevant, i.e. increases at the pressure benchmark could result in loss and detachment. However as this biotope occurs in rock pools (Connor *et al.*, 2004) it will only be exposed for limited periods and rapid growth of *Ulva* sp. may mitigate the loss of tissue during the growing season. A decrease in water flow may have some effects on recruitment by reducing larval supply, but this is not considered to be lethal at the pressure benchmark as the characterizing and associated species produce high numbers of propagules. Biotope resistance to an increase or decrease in flow at the pressure benchmark is assessed as 'High' and resilience is assessed as 'High' (by default), so that the biotope is considered to be 'Not sensitive'.

Increases or decreases in water flow greater than the pressure benchmark may alter the supply of sediment to this biotope, change the nature of the sediments present through deposition or sediment remobilisation and alter scour rates, these changes are considered through the siltation, abrasion and changes in sediment type pressures. Reductions in flow may lead to increased deposition of silts and alter the sediment character, littorinids are found on sediments and may survive some deposition but hydroids, barnacles and mussels and other filter feeders would incur extra energetic costs filtering and clearing feeding apparatus. An increase in water flow at the pressure benchmark may re-suspend and remove sand particles which are less cohesive than mud particles. The level of impact will depend on site specific hydrodynamic and sediment conditions. Wave action is considered to be a more important factor than water flow for this biotope and would be likely to maintain normal rates of sediment deposition, re-suspension and abrasion that support this biotope and prevent succession by fucoids. Resistance is therefore assessed as 'High' and resilience as 'High' so that the biotope is assessed as 'Not sensitive'.

Emergence regime changes

Low

Q: **Low** A: **NR** C: **NR**

High

Q: **High** A: **High** C: **High**

Low

Q: **Low** A: **Low** C: **Low**

The emergence regime over the tidal cycle is an important factor structuring this, and other, intertidal biotopes. An increase in emergence may lead to shallow pools drying out, greater exposure to air temperatures with corresponding fluctuations in water temperature and changes in salinity following evaporation or dilution by rainfall. Mobile species within this biotope could relocate to preferred shore heights but an increase or decrease in abundance of predators and grazers may alter the structure of the assemblage.

As the key characterizing *Ulva* spp. are able to tolerate desiccation stress they are often very abundant on the high shore where desiccation stress is the primary factor controlling seaweed distribution, and may even be found above the tidal limits of the shore. *Ulva intestinalis* (studied as *Enteromorpha intestinalis*) can survive several weeks of living in completely dried out rock pools, while becoming completely bleached on the uppermost layers, but remaining moist underneath the bleached fronds. However, desiccation stress of germlings may be lower than adults. Hruby & Norton (1979) found that 7-14 day old germlings of *Ulva* (studied as *Enteromorpha*) were more tolerant of desiccation than earlier stages, so an increase in desiccation stress may impact more adversely on newly settled germlings than more mature plants. Owing to increased emergence, the species that graze on *Ulva intestinalis* are likely to be less active, owing to the risk of desiccation, and the seaweed may benefit from reduced grazing pressure. Most hydroid species occur subtidally and intertidal hydroids are usually found in rockpools or other moist conditions (Hayward & Ryland, 1995), an increase in emergence may therefore result in the loss of these species, where drying and desiccation increases. Increased emergence may also reduce habitat suitability for the associated barnacle species, *Semibalanus balanoides* and winkles, *Littorina littorea*. However as these occur in higher shore biotopes on bare rock surfaces, an increase in emergence may not directly affect these species, as the retention of water by the rock pool will mitigate increased exposure to air. *Chthamalus* spp. are more tolerant of desiccation stress than *Semibalanus balanoides* and increased emergence may lead to species replacement although this would not alter the character of the biotope.

Decreased emergence may increase habitat suitability for hydroids, the majority of which are found subtidally. *Ulva intestinalis* is unlikely to be directly affected by a decrease in the emergence regime, as it occurs in the subtidal zone, although decreased emergence may enhance habitat suitability for some grazers, increasing predation pressure on *Ulva* spp. An increase in grazers and

grazing within this biotope may removal large amounts of algal biomass preventing blooms. This may be balanced by increased predation from *Carcinus maenas* on *Littorina littorea*.

The blue mussel *Mytilus edulis* occurs within this biotope and the biotope itself may occur in beds of *Mytilus edulis*. *Mytilus edulis* beds are found at a wide range of shore heights from in the strandline down to the shallow sublittoral (Connor *et al.*, 2004). Their upper limits are controlled by temperature and desiccation (Suchanek, 1978; Seed & Suchanek 1992; Holt *et al.*, 1998) while the lower limits are set by predation, competition (Suchanek, 1978) and sand burial (Daly & Mathieson, 1977). Mussels found higher up the shore display slower growth rates (Buschbaum & Saier, 2001) due to the decrease in time during which they can feed and also a decrease in food availability. It has been estimated that the point of zero growth occurs at 55 % emergence (Baird, 1966) although this figure will vary slightly depending on the conditions of the exposure of the shore (Baird, 1966; Holt *et al.*, 1998). Increasing shore height does, however, increase the longevity of the mussels due to reduced predation pressures (Seed & Suchanek 1992; Holt *et al.*, 1998), resulting in a wider age class of mussels found on the upper shore. Growth rates decrease with increasing shore height and tidal exposure, due to reduced time available for feeding and reduced food availability, although longevity increases (Seed & Suchanek, 1992; Holt *et al.*, 1998). It would also increase the risk of desiccation and vulnerability to extreme temperatures. The risk of predation from subtidal and lower intertidal species (e.g. starfish and crabs) will decrease while the predation from birds e.g. oystercatchers (and humans) may increase. This has the potential to reduce their upper limit and overall span on the shore. A decrease in emergence is, however, likely to have a positive effect on *Mytilus* beds as the amount of time available to feed will increase as will the food availability, increasing the growth rate. The risk of desiccation and vulnerability to extreme temperatures will also be reduced by a decrease in emergence, potentially allowing the bed to extend its range on the shore. The lower limit of *Mytilus* beds is mainly set by predation from *Asterias rubens* and *Carcinus maenas* which may increase with a decrease in emergence potentially reducing the lower limit or reducing the number of size classes and age of the mussels at the lower range of the bed (Saier, 2002).

Sensitivity assessment. This biotope develops in areas where sediment instability or sand scour prevents the development of a biotope more typical of rocky shores. As changes in emergence would not alter these structuring factors and the biotope may not change substantially in comparison with a more stable biotope in more sheltered shores where the composition of fucoids and laminarians would reflect the new emergence regime over time. A decrease in emergence would mean that this shallow rock pool would be at less risk of desiccation. In addition, depending on the nature of the surrounding bedrock, the rockpool may become slightly deeper. As a result, it is possible that species diversity could increase as, for example, other hydroids colonized the pool. This could result in increased competition between the suspension feeders but, on the whole, LR.H is likely to be tolerant of a decrease in emergence at the benchmark level. Resistance is therefore assessed as 'High' and resilience as 'High'. The most sensitive component of the biotope to increased emergence are the hydroids. Resistance is assessed as 'Low' and recovery as 'High' (following habitat recovery), so that sensitivity is assessed as 'Low'. The hydroid assessment for increased emergence has been used as the biotope assessment, as the loss of hydroids would alter the biotope classification to LR.FLR.Rkp.G or other LR.FLR. biotope type. It should be noted that intertidal *Mytilus edulis* beds are considered to express 'Medium' resistance (some mortality, loss of <25 % of species abundance or extent) to changes in emergence with mussels at the upper and lower limits exhibiting the greatest effects. Resilience is assessed as 'Medium' and sensitivity is therefore assessed as 'Medium'.

Wave exposure changes (local)**High**

Q: High A: Low C: NR

High

Q: High A: High C: High

Not sensitive

Q: High 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 found on shores where the estimated wave exposure varies from moderately exposed to sheltered (Connor *et al.*, 2004). The degree of wave exposure influences wave height, as in more exposed areas with a longer fetch waves would be predicted to be higher. The occurrence across two wave exposure categories were considered to indicate, by proxy, that biotopes in the middle of the wave exposure range would tolerate either an increase or decrease in significant wave height at the pressure benchmark.

An increase in wave action, exceeding the pressure benchmark, may however alter the character of the biotope. The cobbles and pebbles in the biotope are likely to move much more as a result of increased wave oscillation. The characterizing and associated species would probably accrue damage from abrasion and scour and barnacles trapped on the undersides of overturned pebbles would be unable to feed or respire. In sites with mobile cobbles and boulders increased scour results in lower densities of *Littorina* spp. compared with other, local sites with stable substratum (Carlson *et al.*, 2006). *Littorina littorea* regularly have to abandon optimal feeding sites in order to avoid wave-induced dislodgement. This will result in a decreased growth rate (Mouritsen *et al.*, 1999). Increases in wave exposure above the pressure benchmark will probably cause a decrease in population size of *Littorina littorea*. The hydroid *Obelia longissima* is found in habitats with all levels of wave exposure because the branches and stems are flexible and probably able to withstand oscillatory flow (see Hunter, 1989). The ephemeral green algae and barnacles and mussels and other associated species are found in a range of wave exposures (Connor *et al.*, 2004). Similarly *Semibalanus balanoides* is tolerant of all levels of wave exposure. Changes in wave exposure (greater than the pressure benchmark) are therefore most likely to impact this biotope through impacts on the mixed substrata.

Sensitivity assessment. The natural wave exposure range of this biotope is 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).

🧪 Chemical Pressures**Transition elements & organo-metal contamination****Resistance**

Not Assessed (NA)

Q: NR A: NR C: NR

Resilience

Not assessed (NA)

Q: NR A: NR C: NR

Sensitivity

Not assessed (NA)

Q: NR A: NR C: NR

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

Contamination by non-synthetic chemicals, at levels greater than the pressure benchmark may adversely impact the biotope. The order of metal toxicity to algae varies, with the algal species and experimental conditions, but generally the order is Hg > Cu > Cd > Ag > Pb > Zn (Rice *et al.*, 1973; Rai *et al.*, 1981). The effects of copper on macrophytes have been more extensively studied than the effects of any other metal owing to its use in antifouling paints. Lewis *et al.* (1998) investigated the influence of copper exposure and heatshock on the physiology and cellular stress response of *Ulva intestinalis* (as *Enteromorpha intestinalis*). Heat shock proteins (HSPs) are known to be expressed in

response to a variety of stress conditions, including heavy metals (Lewis *et al.*, 1999). *Ulva intestinalis* was exposed to a range of copper concentrations (0-500 µg -1 for 5 days, to assess the effect of copper exposure on stress proteins (Stress-70 levels) and physiology of the seaweed. Stress-70 was induced by copper exposure, but was found to be no better an indicator of copper exposure than measurement of growth, which is inhibited by copper.

Species of the genus *Ulva* seem to be especially suitable for monitoring heavy metals in coastal areas and estuaries as it is ubiquitous in both and laboratory experiments have shown that accumulation of Cu, Zn, Cd and Pb by four different species of *Ulva* (as *Enteromorpha*) was sufficiently similar to justify pooling samples of the genus for field monitoring (Say *et al.*, 1990). However, the interactions of salinity and temperature with toxicity are not always clear and may hinder cross-comparison of samples and surveys. For instance, Munda (1984) found that the Zn, Mn and Co accumulations in *Ulva intestinalis* (as *Enteromorpha intestinalis*) could be enhanced by decreasing the salinity.

Although no information on the effects of heavy metals on *Obelia longissima* was found, evidence suggests that hydroids may suffer at least sub-lethal effects and possibly morphological changes and reduced growth due to heavy metal contamination. Various heavy metals have been shown to have sublethal effects on growth in the few hydroids studied experimentally (Bryan, 1984). Stebbing (1981) reported that Cu, Cd, and tributyl tin fluoride affected growth regulators in *Laomedea* (as *Campanularia*) *flexuosa* resulting in increased growth. Stebbing (1976) reported that 1 µg/l Hg²⁺ was stimulatory, although the effect was transitory, exposure resulting in reduced growth towards the end of his 11 day experiments. Cadmium (Cd) was reported to cause irreversible retraction of 50 % of hydranths in *Laomedea loveni* after 7 days exposure at concentrations between 3 µg/l (at 17.5°C and 10 ppt salinity) and 80 µg/l (at 7.5°C and 25 ppt salinity) (Theede *et al.*, 1979). *Laomedea loveni* was more tolerant of Cd exposure at low temperatures and low salinities. Karbe (1972, summary only) examined the effects of heavy metals on the hydroid *Eirene viridula* (Campanulidae). He noted that Cd and Hg caused cumulative effects, and morphological changes. Mercury (Hg) caused irreversible damage at concentrations as low as 0.02 ppm. He reported threshold levels of heavy metals for acute effects in *Eirene viridula* of 1.5-3 ppm Zn, 1-3 ppm Pb, 0.1-0.3 ppm Cd, 0.03-0.06 ppm Cu and 0.001-0.003 ppm Hg. Karbe (1972, summary only) suggested that *Eirene viridula* was a sensitive test organism when compared to other organisms.

Although no information on the effects of heavy metals on *Obelia* species was found, the above evidence suggests that hydroids may suffer at least sub-lethal effects and possibly morphological changes and reduced growth due to heavy metal contamination.

Most of the information available suggests that adult gastropod molluscs are rather tolerant of heavy-metal toxicity (Bryan, 1984). Winkles may absorb metals from the surrounding water by absorption across the gills or from the diet, and evidence from experimental studies on *Littorina littorea* suggest that the diet is the most important source (Bryan *et al.*, 1983). Bryan *et al.* (1983) suggest that *Littorina littorea* is a reasonable bioindicator for Ag, Cd, Pb and perhaps As. It is not found to be a reliable indicator for other metals because of some interactions between metals and regulation of some, such as Cu and Zn (Langston & Zhou Mingjiang, 1986). The lethal dose of mercury (as mercury chloride) is between 1 and 10 ppm of seawater (Staines, 1996). This stems mainly from its ability to accumulate trace elements and compounds and consequential behavioural changes.

The effects of contaminants on *Mytilus* sp. were extensively reviewed by Widdows & Donkin (1992) and Livingstone & Pipe (1992). Mussels were reported to be missing from a wider area than

other shore organisms on a Cumbrian shore in the vicinity of a phosphate rich effluent outfall contaminated by a number of heavy metals (Holt *et al.*, 1998).

Semibalanus balanoides is considered to be of low intolerance to heavy metal exposure (see MarLIN review).

Despite the characterizing species showing primarily sublethal effects, the nature of the rockpool, especially those higher up on the shore, may mean that the contaminant takes some time to be flushed from the biotope. This would mean the sublethal effects may manifest themselves into a more adverse reaction. Due to the uncertainty with regards to contaminants leaving the system, a recoverability of high has been suggested.

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 may impact this biotope. Little information of the effects of hydrocarbons on hydroids was found although hydroid species adapted to a wide variation in environmental factors and with cosmopolitan distributions tend to be more tolerant of polluted waters (Boero, 1984; Gili & Hughes, 1995). The water soluble fractions of Monterey crude oil and drilling muds were reported to cause polyp shedding and other sublethal effects in the athecate *Tubularia crocea* in laboratory tests (Michel & Case, 1984; Michel *et al.*, 1986; Holt *et al.*, 1995). However, no information concerning the effects of hydrocarbons or oil spills on *Obelia* species was found.

Ulva intestinalis is likely to demonstrate intolerance to hydrocarbon contamination. Likely effects include smothering, inhibition of respiration and photosynthesis, bleaching, and interference with reproduction so that affected populations may be destroyed. However, the species tends to recover very rapidly from oil pollution incidents. For instance, after the *Torrey Canyon* tanker oil spill in 1967, grazing species were killed, and a dense flush of ephemeral green algae (such as *Ulva* and *Blidingia* sp.) appeared on the rocky shore within a few weeks and persisted for up to one year (Smith, 1968).

Observations from oil spills such as the *Sea Empress* and *Amoco Cadiz* suggest that gastropod molluscs are highly intolerant of hydrocarbon pollution because they become encrusted with oil and washed from the substratum where they are most likely eaten or die from desiccation (Suchanek, 1993). Given that *Littorina littorea* represents the most significant grazer in LR.H, it is likely that its disappearance will lead to a proliferation of ephemeral to the green algae, to the detriment of the hydroids with which the algae may compete for space.

Littoral barnacles have a high resistance to oil (Holt *et al.*, 1995). However, after the *Torrey Canyon* oil spill, some mortality of barnacles was caused by the oil although most had been able to form a hole in the covering of oil and were 'in good order' (Smith, 1968). Significant reductions in densities of *Semibalanus balanoides* were observed after the *Exxon Valdez* oil spill (1989), especially at high and mid shore (Highsmith *et al.*, 1996), although up to 98% reduction in barnacle cover resulted from treatment by hot-water washing. Experimentally, *Semibalanus balanoides* has been found to tolerate exposure to the water-accommodated fraction of diesel oil at 129.4 µg/l for two years (Bokn *et al.*, 1993).

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.

Contamination at levels greater than the pressure benchmark may result in effects. The species richness of hydroid communities decreases with increasing pollution but hydroid species adapted to a wide variation in environmental factors and with cosmopolitan distributions tend to be more tolerant of polluted waters (Boero, 1984; Gili & Hughes, 1995). Stebbing (1981) reported that Cu, Cd, and tributyl tin fluoride affected growth regulators in *Laomedea* (as *Campanularia*) *flexuosa* resulting in increased growth. Stebbing (1981a) cited reports of growth stimulation in *Obelia geniculata* caused by methyl cholanthrene and dibenzanthrene. Bryan & Gibbs (1991) reported that virtually no hydroids were present on hard bottom communities in TBT contaminated sites and suggested that some hydroids were intolerant of TBT levels between 100 and 500 ng/l. No information concerning the intolerance of *Obelia longissima* was found. However, the above evidence suggests that several species of hydroid exhibit sublethal effects due to synthetic chemical contamination and lethal effects due to TBT contamination.

Ulva intestinalis can suffer adverse effects upon viability and receive damage leading to death. Contamination at levels greater than the benchmark may impact this biotope. Some evidence for adverse effects of chemical pollution on the key characterizing species, *Ulva intestinalis*, has been found. Although herbicides tend not to be used directly in the marine environment, they can enter estuarine areas via river discharge and runoff. Paraquat and 3AT were tested for their effects on the settlement, germination and growth of *Ulva* (as *Enteromorpha*) (Moss & Woodhead, 1975). They found that zygotes were able to develop into filaments in the presence of Paraquat at 7 mg/L, but that germination was deferred at higher concentrations. Zygotes demonstrated increased resistance when they settled in clumps on the substratum, and green thalli of *Ulva* were more susceptible than ungerminated zygotes. *Ulva* was more intolerant of 3AT than to Paraquat (Moss & Woodhead, 1975).

Synthetic chemicals used as antifouling agents may be directly introduced into the marine environment. Scarlett *et al.* (1997) analyzed water samples taken from the Plymouth Sound locality for the presence of the s-triazine herbicide, Irgarol 1051, which is an ingredient of antifouling paints used on pleasure boats and ships. Irgarol 1051 was detected at all sampling sites within the Sound; the highest levels were found in close proximity to areas of high boat density, especially where water flow was restricted within marinas, although concentrations within the semi-enclosed Sutton Harbour were less than values predicted from leach rate data. The highest detected concentration of over 120 ng/L significantly inhibited the growth of *Ulva intestinalis* (as *Enteromorpha intestinalis*) spores under laboratory conditions; the no effect concentration was 22 ng/L. Photosynthetic efficiency in the adult frond of *Ulva intestinalis* from Sutton Harbour marina was inhibited by Irgarol 1051 in the laboratory with an EC 50 (72 h) of 2.5 µg/L. A small adverse impact on *Ulva intestinalis* reproduction within harbours is therefore likely.

Following the *Torrey Canyon* tanker oil spill, copious amounts of solvent based detergents were sprayed directly on to the shore. Algae on the higher shore was especially affected, and included *Ulva intestinalis* (as *Enteromorpha intestinalis*) in high level rock pools where it was killed (Smith, 1968).

The effects of contaminants on *Mytilus* sp. were extensively reviewed by Widdows & Donkin (1992) and Livingstone & Pipe (1992).

Barnacles have a low resilience to chemicals such as dispersants, dependant on the concentration and type of chemical involved (Holt *et al.*, 1995) and most *Semibalanus balanoides* were killed in areas treated with dispersants (Smith, 1968). However, the barnacle population suffered indirectly as a result of the mass mortality of grazers. The resultant bloom of algae, and growth of fucoids, within 6 months, grew over and killed surviving barnacles (Hawkins & Southward, 1992).

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

Apart from *Ulva intestinalis*, no information was found concerning the effects of radionuclides on the characterizing and other important species in LR.H and no assessment of sensitivity has been made. *Ulva* sp. are known to be able to acquire large concentrations of radioactive substances from surrounding water. In the vicinity of the Sellafield nuclear plant, England, *Ulva* (as *Enteromorpha*) sp. accumulated zirconium, niobium, cerium and plutonium-239, however the species appeared to be unaffected by the radionuclides (Clark, 1997). Due to the lack of evidence regarding effects on other characterizing species, sensitivity to this pressure was not assessed.

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: High C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: High C: High

Where nutrients and other factors support rapid growth, large blooms of *Ulva* spp. can occur, as these die and decay, they can create anoxic conditions in the water column and the sediments they overlay. Some tolerance for anoxia may therefore be expected that allows a proportion of the population to survive and reproduce during and after these conditions. Vermaat & Sand-Jensen (1987) tested the survival of discs of *Ulva lactuca* during prolonged exposure to anoxia. The 113 mm² discs were taken from wild plants collected in the Roskilde Fjord, Denmark in late autumn. Anoxic conditions were created in the laboratory by bubbling with N₂ gas. Exposure to anoxia for two months did not affect survival but did result in increased respiration and a decrease in growth. Corradi *et al.*, (2006) used similar sized thallus discs from *Ulva* spp. (113 mm²), collected from the lagoon Sacca di Goro (Po River Delta) during spring to test the effects of hypoxia on gamete production for *Ulva* sp. The test oxygen concentrations ranged from 1.78 – 4.02 µmol /L (the benchmark of 2mg/l refers to 64 µmol/L). The exposure to hypoxia was not lethal to the discs and following resumption of normal oxygen conditions gametes were produced.

Hydroids mainly inhabit environments in which the oxygen concentration exceeds 5 ml/l (Gili & Hughes, 1995). Although no information was found on oxygen consumption in *Obelia longissima*. Sagasti *et al.* (2000) reported that epifaunal species (including several hydroids and *Obelia bicuspidata*) in the York River, Chesapeake Bay, tolerated summer hypoxic episodes of between 0.5 and 2 mg O₂/l (0.36 and 1.4 ml/l) for 5-7 days at a time, with few changes in abundance or species composition.

Littorina littorea have a high tolerance for low oxygen conditions and can easily survive 3-6 days of anoxia (Storey *et al.*, 2013). In addition, *Littorina littorea*, is an air breather when emersed, so can

respire during the tidal cycle. The associated species *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). The associated species *Mytilus edulis* is regarded as euryoxic, tolerant of a wide range of oxygen concentrations including zero (Zwaan de & Mathieu, 1992). Diaz & Rosenberg (1995) suggest it is resistant to severe hypoxia. Adult mytilids exhibited high tolerance of anoxia and *Mytilus edulis* is capable of anaerobic metabolism. 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).

It should be noted that tide pools occurring on the mid-shore in areas of wave exposure are likely to be flushed with oxygenated waters during the tidal cycle raising the oxygen levels.

Sensitivity assessment. No direct evidence for the effects of hypoxia on whole *Ulva* spp. in-situ was available. However the results of the laboratory experiments which tested parts of *Ulva* individuals to either prolonged anoxia or short-term hypoxia at levels that exceed the benchmark, indicate that *Ulva* have 'High' resistance to this pressure and 'High' resilience by default. The characterizing *Littorina littorea* species and the associated *Semibalanus balanoides* and *Mytilus edulis* are considered to be 'Not Sensitive' to de-oxygenation at the pressure benchmark. The experiments and observations cited as evidence (Jorgensen, 1980; Barnes *et al.*, 1963) exceed the duration and/or magnitude of the pressure benchmark. As this biotope occurs in wave exposed conditions on the shore some mitigation of hypoxic conditions would be expected from water movements increasing dissolved oxygen in the water column and exposure to air during the tidal emersion cycle. Biotope resistance is therefore assessed as 'High' and resilience as 'High' (no effect to recover from), resulting in a sensitivity of 'Not sensitive'.

Nutrient enrichment

High

Q: Low A: NR C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. The pressure benchmark is set at compliance with Water Framework Directive (WFD) criteria for good status, based on nitrogen concentration (UKTAG, 2014). The criteria for status under the WFD with regard to nutrient enrichment is concerned with the presence or absence of 'blooms' of opportunistic algae, including the key characterizing *Ulva* spp. found in this biotope, that act as indicators of enrichment (eutrophication). The abundance and biomass of these species is used in the implementation of the WFD as indicators to assess condition of waterbodies. The criteria for achieving good status states that there should be: 'limited cover (<15%) and low biomass (<500g/m²) of opportunistic macroalgal blooms...macroalgae cover shows slight signs of disturbance with slight deviation from reference conditions'.

The high abundance and biomass of *Ulva* spp. that characterize this biotope would suggest that this biotope would fail to achieve 'good status'. Theoretically, compliance with good status would require a significant loss of characterizing species, suggesting that the biotope would be sensitive to this pressure at the benchmark (i.e. it represents a significant impact for biotope character). However, the biotope is considered to develop in response to chronic physical disturbance from sediment instability or sand-scour and wave exposure and therefore its presence is not necessarily an indicator of abnormal nutrient loading. Typical blooms of opportunistic macroalgae, occur in

sheltered areas such as estuaries (Kennison & Fong, 2013) and are likely to form as unattached mats over sediments rather than rocky shores, the character of these is therefore different to the assessed biotope.

Opportunistic algae, including *Ulva* spp. cannot store nutrients in the thallus (unlike larger, long-lived species) and are adapted to efficiently capture and utilize available nutrients in the water column (Pedersen *et al.*, 2009). A large body of field observations and experiments, surveys and laboratory experiments confirm that the characterizing *Ulva* spp. can utilize high levels of nutrients for growth (Martínez *et al.*, 2012) and that enhanced recruitment (Kraufvelin, 2007) and growth of this genus can occur in enriched areas (Kennison & Fong, 2013, Vaudrey *et al.*, 2010). In areas where nutrient availability is lower either naturally or through management to reduce anthropogenic inputs, *Ulva* spp. may be negatively affected through reduced growth rate and species replacement (Martínez *et al.*, 2012; Vaudrey *et al.*, 2010).

Sensitivity assessment. If nutrient levels were to increase (exceeding the pressure benchmark) enhanced growth of *Ulva* spp. would be expected in response and this is not considered to significantly alter the character of the biotope. *Ulva* spp. may decline in response to reductions in nutrient levels, in habitats where other species more typical of undisturbed species are able to recolonize. However, as this biotope is structured by disturbance rather than nutrient enrichment, other species are not considered to establish following decreases in nutrient levels and *Ulva* spp. would be likely to remain among the dominant species. As the pressure benchmark is relatively protecting the hydroids and littorinids and other associated species are considered to be unaffected by this pressure. The biotope is therefore considered to have 'High' resistance to this pressure and 'High' resilience, (by default) and is assessed as 'Not sensitive'.

Organic enrichment

High

Q: Medium A: Low C: Low

High

Q: High A: High C: High

Not sensitive

Q: Medium A: Low C: Low

Organic enrichment may lead to eutrophication with adverse environmental effects including deoxygenation, algal blooms and changes in community structure (see nutrient enrichment and deoxygenation). The biotope occurs in 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. Little evidence was found to support this assessment, Cabral-Oliveira *et al.* (2014), found that filter feeders associated with this biotope such as *Mytilus* sp. and the barnacle *Chthamalus montagui*, were more abundant at sites closer to a sewage treatment works, as they could utilise the organic matter inputs as food. Deposit feeders present in the sediment patches in this biotope, including *Arenicola marina* and *Lanice conchilega* may also consume deposited organic matter. Empirical observations in the Weser estuary (Germany) found that the hydroid *Obelia* spp. were more abundant in a sewage disposal area (with sedimentation of 1 cm for more than 25 days), but *Sertularia cupressina* was significantly reduced in abundance when compared with unimpacted reference areas (Witt *et al.*, 2004). Borja *et al.* (2000) and Gittenberger & van Loon (2011) when developing the AZTI Marine Biotic Index (AMBI I) a biotic index to assess disturbance (including organic enrichment) both assigned *Obelia longissima* to AMBI Ecological Group II (Borja *et al.*, 2000; Gittenberger & van Loon, 2011). The group definition is 'species considered indifferent to enrichment, always present in low densities with non-significant variations with time'. No AMBI categorisation was found for other hydroids.

Sensitivity assessment. No empirical evidence was found to support an assessment for the key characterizing *Ulva* spp., and *Littorinas littorea* or the associated species; *Semibalanus balanoides* that are present at low abundances within this biotope. As re-suspended or deposited

organic matter particles could potentially be utilized as a food resource by the filter and deposit feeders present within the biotope (Cabral-Oliveira *et al.*, 2014) and as *Obelia* spp. are likely to tolerate organic matter the overall 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'.

A 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: Low C: NR	Very Low Q: High A: High C: High	High Q: High A: Low C: NR
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This biotope is characterized by the mixed substratum provided by the boulders and cobbles and mixed sediments which retain water to create tide pools (Connor *et al.*, 2004). Changes to a free draining sediment type or to an impervious artificial substratum that was free draining would significantly alter the character of the biotope through the loss of the pool and hydroids. The characteristic *Littorina littorea* and *Ulva* sp. are found on hard rock substrata, as are the sediments outside of pools with the associated *Mytilus edulis* and *Semibalanus balanoides* (the latter where there is sufficient hard substratum to attach). Other species associated with the pools such as *Cragon crangon* would be lost and a change to a hard substratum would result in the loss of sedimentary species.

Sensitivity assessment. The biotope is considered to have 'No' resistance to this pressure based on a change to a soft sediment substratum or a hard, free draining substratum. Recovery of the biological assemblage (following habitat restoration, including the restoration of *Mytilus edulis* beds of which this biotope classification depends on), is considered to be 'High', although the re-establishment of littorinids may require longer depending on the footprint of the impact. However, as the change at the pressure benchmark is considered permanent, biotope recovery is assessed as 'Very low'. Sensitivity is therefore categorised 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
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Not relevant to biotopes occurring on bedrock or on mixed substrata consisting of boulders, cobbles and pebbles.

Habitat structure changes - removal of substratum (extraction)**None**

Q: High A: High C: High

Medium

Q: Low A: NR C: NR

Medium

Q: Low A: Low C: Low

The process of extraction on mixed substrata will remove the entire biotope and the associated community; therefore a resistance of 'None' is recorded. Resilience is assessed as 'High', for the key characterizing hydroids and *Ulva* spp., and Medium-High for *Littorina littorea* (depending on the footprint of the impact and hence limitations on colonisation from adjacent habitats). Sensitivity is, therefore, assessed as 'Medium'.

Abrasion/disturbance of the surface of the substratum or seabed**Medium**

Q: High A: Medium C: High

High

Q: High A: Low C: High

Low

Q: High A: Low C: High

The existence of LR.FLR.H is, in some respects, dependent on the influence of physical disturbance such as sand scour. LR.FLR.H is dominated by ephemeral hydroids and seaweeds which thrive due to the disturbed nature of the habitat which prevents their competitive exclusion by late successional species. However, abrasion could potentially destroy parts of the biotope, depending on the size of the pool and on the size of the impact.

No direct evidence was found to assess how the key, characterizing, *Ulva* spp. respond to surface abrasion. The fronds are very thin and could be torn and damaged and individuals may be removed from the substratum, altering the biotope through changes in abundance and biomass. *Ulva* spp. cannot repair damage or reattach but torn fronds could still photosynthesise and produce gametes. Tearing and cutting of the fronds has been shown to stimulate gamete production and damaged plants would still be able to grow and reproduce. *Ulva* spp. can also form unattached mats (particularly in response to nutrient enrichment): damage and removal may, therefore, not lead to mortality of impacted individuals.

The available evidence indicates that hydroids can be entangled and removed by abrasion. Drop down video surveys of Scottish reefs exposed to trawling showed that visual evidence of damage to bryozoans and hydroids on rock surfaces was generally limited and restricted to scrape scars on boulders (Boulcott & Howell, 2011). The study showed that damage is incremental with damage increasing with frequency of trawls rather than a blanket effect occurring on the pass of the first trawls (Tillin & Tyler-Walters, 2014). Re-sampling of grounds that were historically studied (from the 1930s) indicates that some species have increased in areas subject to scallop fishing (Bradshaw *et al.*, 2002). This study also found increases in the tough stemmed hydroids including *Nemertesia* spp., whose morphology may prevent excessive damage. Bradshaw *et al.*, (2002) suggested that as well as having high resistance to abrasion pressures, *Nemertesia* spp. have benthic larvae that could rapidly colonize disturbed areas with newly exposed substrata close to the adult. Hydroids may also recover rapidly as the surface covering of hydrorhizae may remain largely intact, from which new uprights are likely to grow. In addition, the resultant fragments of colonies may be able to develop into new colonies.

The barnacles and littorinids and other associated species that occur in this biotope, have some protection from hard shells or plates but abrasion may damage and kill individuals or detach these. All removed barnacles would be expected to die as there is no mechanism for these to reattach. Although littorinids and mussels may be able to repair shell damage, broken shells while healing will expose the individual to more risk of desiccation and predation. Evidence for the effects of

abrasion are provided by a number of experimental studies on trampling (a source of abrasion) and on abrasion by wave thrown rocks and pebbles. The effects of trampling 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 & Crumrine (1994) who found 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 (*Semibalanus glandula* and *Chthamalus dalli*) 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/hrs) led to reductions in barnacle cover. Single step experiments provide a clearer, quantitative indication of sensitivity to single events of direct abrasion. Povey & Keough (1991) in experiments on shores in Mornington peninsula, Victoria, Australia, found that in single step experiments 10 out of 67 barnacles, (*Chthamlus antennatus* about 3 mm long), were crushed. On the same shore less than 5% of littorinids were crushed in single step experiments (Povey & Keough, 1991). Shanks & Wright (1986), found that even small pebbles (<6 cm) that were thrown by wave action in Southern California shores could create patches in aggregations of the barnacle, *Chthamalus fissus*, and could smash owl limpets (*Lottia gigantea*). Average, estimated survivorship of limpets at a wave exposed site, with many loose cobbles and pebbles allowing greater levels of abrasion was 40 % lower than at a sheltered site. Severe storms were observed to lead to almost total destruction of local populations of limpets through abrasion by large rocks and boulders. In sites with mobile cobbles and boulders increased scour results in lower densities of *Littorina* spp. compared with other, local sites with stable substratum (Carlson *et al.*, 2006).

Sensitivity assessment. The impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure. In response to a single event of abrasion a proportion of the *Ulva* and hydroid population may be removed, but *in-situ*, damaged individuals would be capable of growth and reproduction. Based on additional evidence for the associated species from the step experiments and the relative robustness of the associated species, the resistance of the biotope, to a single abrasion event is assessed as 'Medium' and recovery as 'High', so that sensitivity is assessed as 'Low'. Resistance will be lower (and hence sensitivity greater) to abrasion events that exert a greater crushing force than the trampling examples the assessment is based on. Mainwaring *et al.*, (2014) reviewed the effects of abrasion on intertidal mussel beds. Based on the available evidence they concluded that all mussel biotopes are sensitive to abrasion and that resistance is 'Low' (loss of 25-75% of bed within direct impact footprint), resilience should be assessed as 'Medium', resulting in a sensitivity of 'Medium'. Where adjacent beds are important in the development or maintenance of this biotope, for example, by stabilising sediments then damage to beds may prolong the recovery of this biotope.

Penetration or disturbance of the substratum subsurface

Low

Q: **Low** A: **NR** C: **NR**

High

Q: **High** A: **Low** C: **High**

Low

Q: **Low** A: **Low** C: **Low**

No direct evidence was found to assess this pressure. Penetration and disturbance below the surface would result in direct physical damage and/or detachment of key characterizing and associated species. The overturning of boulders and cobbles would result in individuals being smothered or unable to photosynthesise, filter-feed or respire in air. Although the mobile littorinids may be able to reposition a proportion of the population would be likely to be

smothered (see siltation pressures). Although littorinids may be able to repair shell damage, however, whilst the broken shells are healing, the individual will be more at risk of desiccation and predation.

Sensitivity assessment. The impact of sub-surface disturbance will depend on the footprint, duration and magnitude of the pressure. In response to a single event a proportion of the population of the key characterizing hydroid species *Ulva* spp. and *Littorina littorea* as well as associated species may be damaged buried or removed but damaged individuals, *in-situ* would be capable of growth and reproduction. Resistance of the biotope, to a single disturbance event at the pressure benchmark is assessed as 'Low' and recovery as 'High', so that sensitivity is assessed as 'Low'. It should be noted that abrasion and other disturbance factors such as sediment instability are important to the maintenance of this biotope. However, this is due to rapid recovery of key characterizing species, rather than tolerance of disturbance. The opportunistic species *Ulva* and hydroids can rapidly colonise where cleared surfaces and removal of predators allows the development of a bloom (Robles, 1982).

Changes in suspended solids (water clarity)

High

Q: High A: Low C: Medium

High

Q: High A: High C: High

Not sensitive

Q: High A: Low C: Medium

Increased organic matter in suspension may enhance food supply to barnacles and mussels and other suspension feeders including *Spirobranchus* (formerly *Pomatoceros*) spp. and *Lanice conchilega*. However, an increase in inorganic solids may result in a decrease in feeding efficiency. Moreover, because the rockpool has a 'pulsed' influx of water, the suspended sediment is likely to settle between tides and increase the depth of sediment in the pool (see siltation pressures). Some smaller immobile species including barnacle and tubeworms may be temporarily smothered. Suspended sediments may also have abrading effects on the species present. Tolhurst *et al.* (2007) found that *Ulva intestinalis* germlings kept in tanks and exposed to 100 mg/l of suspended sediment showed reduced growth. Similarly, Hyslop *et al.* (1997) found that *Ulva lactuca* lost weight when kept in flasks with 1 g/l of colliery waste that was shaken for 1 hour every day for 8 days. The experimental solids level, however, exceeds the pressure benchmark. Other species within the biotope such as the mussels and barnacles may withdraw into the shells/plates or in the case of hydroids withdraw polyps into the perisarc (a tough sheath) to avoid abrasion from suspended solids.

A decrease in suspended sediment is likely to benefit the community associated with LR.H. The suspension feeders may be able to feed more efficiently due to a reduction in time and energy spent cleaning feeding apparatus. Over the course of the benchmark the hydroids may increase in abundance and the mussels may experience an enhanced scope for growth. An associated decrease in turbidity is likely to enhance primary productivity within the biotope by *Ulva* spp and other primary producers including algal films and phytoplankton within pools and the sea. This could enhance secondary production by increasing the food supply to grazers including *Littorina littorea* and suspension feeders (*Mytilus edulis*, hydroids and *Semibalanus balanoides* that capture phytoplankton. Bourget *et al.* (2003), for example, noted that for any given water temperature on buoys in the Gulf of St Lawrence, water transparency and primary production influenced the biomass of fouling organisms, including *Obelia longissima*. Biomass was reported to increase with increasing transparency up to a transparency of 15 m after which it decreased again. Increased transparency was presumably correlated with increased primary production and hence food availability. Where the suspended solids are organic in origin a reduction may reduce food availability, however, this may be compensated by increased phytoplankton production.

Sensitivity assessment. The exposure of this upper shore biotope to suspended sediments in the water column will be limited to the short immersion periods, however silts deposited on the fronds of *Ulva* spp. and on hydroids and other species during emersion may remain on the fronds inhibiting photosynthesis and suspension feeding in pools and there may be some sub-lethal abrasion. An increase in inorganic suspended solids may result in sublethal decreases in feeding efficiency and photosynthesis. The biotope is considered to be 'Not sensitive' to either a reduction or increase in suspended solids. Resistance is therefore assessed as 'High' and resilience as 'High' (by default) so that the biotope is considered to be 'Not sensitive'.

Smothering and siltation rate changes (light)

Low

Q: High A: Medium C: Medium

High

Q: High A: Low C: High

Low

Q: High A: Low C: Medium

Obelia longissima forms long flexible colonies so that smothering material is likely to bend the colony flat against the substratum. In addition, local hypoxic conditions are also likely to inhibit growth. Although hydranths are likely to regress and portions of the colony are likely to die or be reabsorbed, parts of the colony are likely to become dormant, or otherwise survive for a period of at least a month. *Ulva intestinalis* is highly intolerant to smothering due to its filamentous form. It is likely to be completely smothered at the benchmark level and photosynthesis would be prevented due to lack of light. Furthermore, the thin fronds of the algae may start to rot.

Observations and experiments indicate that *Ulva* spp. have relatively high tolerances for the stresses induced by burial (darkness, hypoxia and exposure to sulphides). Vermaat & Sand-Jensen, (1987) exposed thallus discs (113 mm²) of *Ulva lactuca* to darkness and anoxia and sulphides at winter temperatures. It was found that these conditions did not affect survival over two months, although exposure to anoxia increased respiration and reduced growth (Vermaat & Sand-Jensen, 1987). These experiments were undertaken using *Ulva lactuca* collected from Roskilde Fjord, Denmark. Corradi *et al.* (2006) subjected *Ulva* sp. collected from the Sacca di Goro, Italy to similar stressors (hypoxia 1.78 – 4.02 µmol /L, or sulphide at 1 mM, both treatments in darkness) for 3,5 or 7 days at 20°C. The thallus discs survived but no gametes were produced until recovery in oxygenated conditions. The high tolerance of darkness, anoxia and hydrogen sulphides allows buried fragments of *Ulva* sp. to overwinter, protected from frosts. Kamermans *et al.*, (1998) found that parts of *Ulva* thalli that were collected from the Veerse Meer lagoon in the Netherlands could resume growth in the spring when returned to the surface. *Ulva* spp. in sheltered areas are often unattached to the substratum and therefore are not considered a direct proxy for attached *Ulva* spp. in this biotope.

Although *Ulva* spp. present in sedimentary habitats may be able to survive the chemical stress of burial and re-grow from surviving fragments, evidence for attached individuals from rocky shores suggest that resistance to this pressure may be lower. *Ulva lactuca* is a dominant species on sand-affected rocky shores in New Hampshire (Daly & Mathieson, 1977) although Littler *et al.*, (1983) suggest that *Ulva* sp., are present in areas periodically subject to sand deposition not because they are able to withstand burial but because they are able to rapidly colonize sand-scoured areas (such as this biotope). *Ulva* spp. have, however, been reported to form turfs that trap sediments (Airoldi, 2003, references therein) suggesting that resistance to chronic rather than acute siltation events may be higher. In general, propagules, early post-settlement stages and juveniles suffer severe stress and mortality from sediments (Airoldi, 2003). Hyslop *et al.* (1997) compared the composition, abundance and distribution of dominant plants and animals at several rocky shores affected or unaffected by dumping of colliery wastes along the coastline of northeast England. They reported that while the distribution of animals was not related to colliery wastes, diversity of

macroalgae was significantly negatively correlated with colliery waste inputs and particularly dramatic reductions in cover at the affected sites were observed for *Ulva lactuca*. The authors suggested that, because colliery waste leaches much of its toxic chemical content into the sea, detrimental effects were most likely related to the physical presence of sediments.

The associated species, *Semibalanus balanoides* and *Littorina littorea* are likely to be negatively affected by siltation. 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 Hampshire (Daly & Mathieson, 1977), suggesting that this species is sensitive to the deposition of relatively coarse sediments, although whether this is due to repeated scour events removing juveniles rather than siltation effects (i.e. smothering, prevention of feeding) is not clear. Chandrasekara & Frid (1998) specifically tested the siltation tolerance of *Littorina littorea*. Burial to 5 cm caused mortality within 24 hours at simulated summer and winter temperatures if the snails could not crawl out of the sediment (Chandrasekara & Frid, 1998). If the sediment is well oxygenated and fluid (as with high water, high silt content) a few snails (1-6 out of 15 in the experiment, depending on temperature, sediment and water content) may be able to move back up through 5 cm of sediment (Chandrasekara & Frid, 1998). Approximately half of the test individuals could not regain the surface from 1cm of burial except in the most favourable conditions (low temperatures, high water, high silt when a majority (10 out of 15) of the test cohort surfaced. Field observations support the findings that *Littorina littorea* are generally unable to survive smothering. Albrecht & Reise (1994) observed a population of *Littorina littorea* in a sandy bay near the Sylt island in the North Sea. They found that the accretion of mud within *Fucus* strands and subsequent covering of *Littorina* by the sediment resulted in them suffocating and a significant reduction in their abundance.

Sensitivity assessment. The available evidence indicates that *Ulva* spp. can survive some of the stressors associated with burial but would be sensitive to abrasion and scouring forces resulting from the deposition and removal of sediments. Even small deposits of sediments are likely to result in local removal of *Littorina littorea* are considered to have 'Low' resistance to this pressure. The sensitivity assessment for the biotope is based on *Ulva* spp. and hydroids. Siltation by 5 cm of fine sediments is considered to remove a proportion of the population through scour effects and resistance is assessed as 'Low', recovery is assessed as 'High' and sensitivity is assessed as 'Low'.

Smothering and siltation rate changes (heavy)

Low

Q: High A: Low C: Medium

High

Q: High A: Medium C: High

Low

Q: High A: Medium C: High

No direct evidence was found to assess the impact of this pressure at the pressure benchmark. As the members of this ecological group are attached to the substratum and are usually shorter than 30 cm (*Nemertesia ramosa* and *Sertularia argentea* are typically about 15 cm in height; *Obelia longissima* is up to 20 cm in length but may reach 35 cm in British waters (Tyler-Walters, 2003), this ecological group would be buried by the deposit and unable to migrate to the surface. Siltation by fine sediments would also prevent larval settlement by this ecological group which requires hard substratum (Berghahn & Offermann 1999). The intensity and duration of siltation will be mediated by site-specific hydrodynamic conditions, such as water-flow and wave action that determine the dispersal of deposits, in pools the sediments may remain for some time, exacerbating the pressure.

In general it appears that hydroids are sensitive to silting (Boero 1984; Gili & Hughes 1995) and decline in beds in the Wadden Sea has been linked to environmental changes including siltation.

Round *et al.* (1961) reported that the hydroid *Sertularia* (now *Amphisbetia*) *operculata* died when covered with a layer of silt after being transplanted to sheltered conditions. Boero (1984) suggested that deep water hydroid species develop upright, thin colonies that accumulate little sediment, while species in turbulent water movement were adequately cleaned of silt by water movement.

Observations and experiments indicate that *Ulva* spp. have relatively high tolerances for the stresses induced by burial (darkness, hypoxia and exposure to sulphides). Vermaat & Sand-Jensen, (1987) exposed thallus discs (113 mm²) of *Ulva lactuca* to darkness and anoxia and sulphides at winter temperatures. It was found that these conditions did not affect survival over two months, although exposure to anoxia increased respiration and reduced growth (Vermaat & Sand-Jensen, 1987). These experiments were undertaken using *Ulva lactuca* collected from Roskilde Fjord, Denmark. Corradi *et al.*, (2006) subjected *Ulva* sp. collected from the Sacca di Goro, Italy to similar stressors (hypoxia 1.78 – 4.02 µmol /L, or sulphide at 1mM, both treatments in darkness) for 3, 5 or 7 days at 20°C. The thallus discs survived but no gametes were produced until recovery in oxygenated conditions. The high tolerance of darkness, anoxia and hydrogen sulphides allows buried fragments of *Ulva* sp. to overwinter, protected from frosts. Kamermans *et al.* (1998) found that parts of *Ulva* thalli that were collected from the Veerse Meer lagoon in the Netherlands could resume growth in the spring when returned to the surface. *Ulva* spp. in sheltered areas are often unattached to the substratum and therefore are not considered a direct proxy for attached *Ulva* spp. in this biotope.

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The associated species, *Semibalanus balanoides* and *Littorina littorea* are likely to be negatively affected by siltation. 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 Hampshire (Daly & Mathieson, 1977), suggesting that this species is sensitive to the deposition of relatively coarse sediments, although whether this is due to repeated scour events removing juveniles rather than siltation effects (i.e. smothering, prevention of feeding) is not clear. Chandrasekara & Frid (1998) specifically tested the siltation tolerance of *Littorina littorea*. Burial to 5 cm caused mortality within 24 hours at simulated summer and winter temperatures if the snails could not crawl out of the sediment (Chandrasekara & Frid, 1998). If the sediment is well oxygenated and fluid (as with high water, high silt content) a few snails (1-6 out of 15 in the experiment, depending on temperature,

sediment and water content) may be able to move back up through 5 cm of sediment (Chandrasekara & Frid, 1998). Approximately half of the test individuals could not regain the surface from 1cm of burial except in the most favourable conditions (low temperatures, high water, high silt when a majority (10 out of 15) of the test cohort surfaced. Field observations support the findings that *Littorina littorea* are generally unable to survive smothering. Albrecht & Reise (1994) observed a population of *Littorina littorea* in a sandy bay near the Sylt island in the North Sea. They found that the accretion of mud within *Fucus* strands and subsequent covering of *Littorina* by the sediment resulted in them suffocating and a significant reduction in their abundance.

Sensitivity assessment. The available evidence indicates that *Ulva* spp. can survive some of the stressors associated with burial but would be sensitive to abrasion and scouring forces resulting from the deposition and removal of sediments. The hydroids within the biotope are likely to die and other associated species are likely to be smothered. Siltation by 30 cm of fine sediments is considered to remove a proportion of the population through smothering and scour effects and resistance is assessed as 'Low', recovery is assessed as 'High' (based on hydroids and *Ulva* spp.) and biotope sensitivity is, therefore, assessed as 'Low'.

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

Not assessed.

Electromagnetic changes

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.

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.

Introduction of light or shading

High

Q: High A: Low C: Low

High

Q: High A: High C: High

Not sensitive

Q: High A: Low C: Low

A number of experiments have demonstrated that the key characterizing species *Ulva lactuca*, has high tolerance for shading and can survive periods of darkness. Vermaat & Sand-Jensen (1987) found that *Ulva lactuca*, collected from Roskilde Fjord in Denmark in late autumn had extremely high shade tolerances. Increasing chlorophyll concentration and light absorption allowed the individuals (studied experimentally as thallus discs of 113 mm²) to continue to grow at the lowest irradiance tested (0.6 $\mu\text{E m}^2/\text{s}$). This corresponds to the lowest light-levels of deep-living marine macroalgae and phytoplankton growing under ice (Vermaat & Sand-Jensen, 1987). *Ulva lactuca* was able to survive two months in darkness and was able to resume growth immediately when transferred to the light (Vermaat & Sand-Jensen, 1987).

No direct evidence to assess this pressure was found for the littorinids. As both species occur on open rock and in crevices and under *Fucus* canopies they are considered tolerant of a range of light

conditions. Light levels have, however been demonstrated to influence a number of phases of the reproductive cycle in *Semibalanus balanoides*. 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 for this species.

Sensitivity assessment. Changes in light levels from anthropogenic sources may have the potential to alter reproduction in *Semibalanus balanoides*, however it is not clear how these effects would ramify to the population level. The key *Ulva* spp. that characterizes the biotope are considered to have 'High' resistance to changes in light level, although extreme changes such as complete darkness would prevent photosynthesis and growth and high light levels may be damaging. Recovery is assessed as 'High' by default and the biotope is judged to be 'Not sensitive'.

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. The key characterizing *Ulva* spp. produce large amounts of motile swimmers, throughout the growing season (Niesenbaum, 1988). The level of supply of potential recruits is considered to be so great that barriers and changes in tidal excursion will not negatively impact populations. The associated species *Patella vulgata* and *Semibalanus balanoides* also produce planktonic larvae that are transported by water movements. Barriers that reduce the degree of tidal excursion may alter larval supply to suitable habitats from source populations. Conversely the presence of barriers may enhance local population supply by preventing the loss of larvae from enclosed habitats. *Littorina saxatilis* have either limited dispersal or produce crawl away juveniles rather than pelagic larvae (direct development). Barriers and changes in tidal excursion are not considered relevant to these species as dispersal is limited. As the key characterizing *Ulva* spp. 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	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

Key characterizing species within this biotope are not cultivated or translocated. This pressure is therefore considered 'Not relevant' to this biotope group' although the associated species *Mytilus edulis* may be dredged and transplanted. No direct evidence was found regarding the potential for negative impacts of translocated mussel seed on adjacent natural beds by Mainwaring *et al.* (2014). 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). Hybrid beds perform the same ecological functions as *Mytilus edulis* so that any impact relates to genetic integrity of a bed alone. Also, given the uncertainty in identification of the species, habitats or biotopes described as *Mytilus edulis* dominated, may well be dominated by *Mytilus galloprovincialis*, their hybrids or a mosaic of the three. Presently, there is no evidence of impact due to genetic modification and translocation, however, the range of *Mytilus galloprovincialis* is thought to be extending northwards (Beaumont *et al.*, 2007) and this assessment may require updating in the future.

	Low	Very Low	High
Introduction or spread of invasive non-indigenous species	Q: High A: Low C: Low	Q: Low A: NR C: NR	Q: Low A: Low C: Low

This biotope occurs where physical disturbance from wave action and sediment scour and associated abrasion prevent the development of a more diverse rocky shore assemblage. Due to the environmental stressors that maintain the biotope (wave action, sediment mobility, sediment abrasion) the habitat is unsuitable for colonization by most species including invasive, non-indigenous species such as *Sargassum muticum* and *Crepidula fornicata*. This biotope is considered to be most vulnerable to the establishment of invasive non-indigenous species that can out-compete the native species for space or prey on them.

The non-native hydroid, *Cordylophora caspia*, may compete directly with native species for food and space but it is found in estuaries and brackish water (from 2-17 psu). In areas of full salinity the LR.FLR.H biotope is unlikely to provide suitable habitat (Sweet, 2011i).

A number of INIS that can settle and occupy hard substratum may threaten this biotope in the future if they become established. The tunicates *Didemnum vexillum* and *Asterocarpa humilis*, the hydroid *Schizoporella japonica* and the bryozoan *Watersipora subatra* (Bishop, 2012c; Bishop, 2015a and b; Wood, 2015) are currently only recorded from artificial hard substratum in the UK and it is not clear what their established range and impacts in the UK would be. *Didemnum vexillum* occurs in tide pools in other areas where it has become established (Bishop, 2012c) and can have substantial effects on communities, similarly the tunicates *Corella eumyota* and *Botrylloides violaceus* can smother rock habitats (Bishop, 2012c, Bishop, 2015a and b; Wood, 2015) but it is not clear whether these species could tolerate the environmental stressors associated with this biotope.

In Canada green sea fingers *Codium fragile fragile* (formerly *Codium fragile* subsp *tormentosoides*), has displaced native seaweed species and become the dominant canopy species in some areas, consequently altering community structure and composition, where conditions permit. Most significant impacts have occurred where algal diversity in the invaded area is low. In Great Britain algal diversity is high and green sea fingers has not yet occurred in nuisance densities (Sweet, 2011j). Generally this species occurs on more sheltered shores and in estuaries and this biotope is probably unsuitable. However, this assessment may need updating in the future if the risk changes.

The Japanese skeleton shrimp, *Caprella mutica* and the tunicate *Perophora japonica* have been recorded growing on hydroids including *Nemertesia antennina* (Essink & Bos, 1985, Sweet, 2012b) although no evidence to suggest a significant impact was available for these species.

The non-native crab *Hemigrapsus sanguineus* has recently been recorded in the UK (Sweet & Sewell, 2014) and has the potential to be a significant predator of intertidal invertebrates. Significant reductions in common shore crab abundance and mussel density have been reported where the Asian shore crab has achieved high densities in mainland Europe (Sweet & Sewell, 2014). This crab occurs on exposed shores and may therefore occur in this biotope when established.

The most significant potential INIS is the Pacific oyster *Magallana gigas*, as its distribution and environmental tolerances are considered to overlap with this biotope. *Magallana gigas* has been associated with *Mytilus edulis* beds that are found in association with this biotope. No evidence was found for effects on rock pools, although on the Mediterranean coast *Magallana gigas* is cultivated in micro-tidal lagoons and has established wild populations (Miossec *et al.*, 2009, cited from Herbert *et al.*, 2012).

In the Wadden Sea and North Sea, *Magallana gigas* overgrows mussel beds in the intertidal zone (Diederich, 2005, 2006; Kochmann *et al.*, 2008), although larvae did show preference for settling on conspecifics before the mussels and struggled to settle on mussels with a fucoid covering. 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). Padilla (2010) predicted that *Magallana gigas* could either displace or overgrow mussels on rocky and sedimentary habitats of low or high energy. Kent and Essex Inshore Fisheries and Conservation Authority (IFCA) (cited in Herbert *et al.*, 2012) reported that *Magallana gigas* had developed a significant stock on mussel beds on the Southend foreshore and that, by 2012, there were few mussels left in the affected area, but made no conclusions as to the reason for the decline in mussels (Kent and Essex IFCA pers comm cited in Herbert *et al.*, 2012).

Dense aggregations of *Magallana gigas* on a former mussel bed showed increased abundance and biomass of *Littorina littorea* in the Wadden Sea (Markert *et al.*, 2010). However, Eschweiler & Buschbaum (2011) found that juvenile *Littorina littorea* could carry *Magallana gigas* and *Crepidula fornicata* as epibionts. Body dry weight of snails without oyster overgrowth was twice as high compared to winkles covered with oysters. Also crawling speed of snails with oyster epigrowth was significantly reduced and about ten times lower than in unfouled periwinkles. Additionally, oyster epibionts caused a strong decrease in reproductive output. In laboratory experiments, egg production of fouled *Littorina littorea* was about 100-fold lower than in affected individuals. Field surveys in different years and habitats demonstrated that up to 10% of individuals occurring on epibenthic bivalve beds and up to 25% of snails living on sand flats may be fouled by *Magallana gigas*. Hydroids and ephemeral algae and other attached species associated with this biotope including tubeworms and barnacles may grow on *Magallana gigas* so that effects on these species

are not directly negative. However, the conversion of this biotope to a *Magallana gigas* reef would present a significantly negative impact.

Sensitivity assessment. Based on the high-levels of environmental stress and the lack of habitat overlap and reported impacts with currently recognised invasive, non-indigenous species, this biotope is considered to have 'High' resistance and 'High' resilience to this pressure and is therefore assessed as 'Not sensitive' to all currently recorded INIS with the exception of *Magallana gigas* which may form reefs on adjacent mussel beds and overgrow the habitat outcompeting hydroids and algae for space. No direct evidence was found to assess this pressure. Resistance was assessed as 'Low' as the habitat may be converted, at least partially, to a *Magallana gigas* reef and resilience as 'High' following eradication, so that sensitivity is assessed as 'Low'. If oysters could not be removed then resilience would be assessed as 'Very Low' and sensitivity to this permanent change would be 'High'. The more precautionary assessment is shown in the table. Future warming trends may exacerbate *Magallana gigas* establishment and this assessment may need to be updated to account for changes in the population status of this and other INIS.

Introduction of microbial pathogens

High

Q: Low A: NR C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

No evidence was found that outbreaks of microbial pathogens significantly impact populations of the key characterizing *Ulva* and hydroid spp. The characterizing littorinids and the associated *Semibalanus balanoides* are considered to be subject to persistent, low levels of infection by pathogens and parasites. At usual levels of infestation these are not considered to lead to high levels of mortality. Parasitism by trematodes may cause sterility in *Littorina littorea*. *Littorina littorea* are also parasitized by the boring polychaete, *Polydora ciliata* and *Cliona sp.*, which weakens the shell and increases crab predation (Stefaniak *et al.*, 2005). Mainwaring *et al.*, (2014) considered that mussel beds, which may be associated with this biotope on some shores, may have 'Medium' sensitivity ('Medium' resistance and resilience) to Marteiliosis caused by a shellfish pathogen.

Sensitivity assessment. Based on the characterizing species and the lack of evidence for widespread, high-levels of mortality due to microbial pathogens the biotope is considered to have 'High' resistance to this pressure and therefore 'High' resilience (by default), the biotope is therefore considered to be 'Not sensitive'.

Removal of target species

Low

Q: High A: High C: NR

High

Q: High A: High C: High

Low

Q: High A: High C: Low

The sensitivity assessment for this pressure considers any biological effects resulting from the removal of target species on the biotope. Damage caused by direct physical impacts are assessed through the 'abrasion' and 'penetration and/or disturbance of the surface of the seabed' pressures. Within this biotope the winkles *Littorina littorea*, the blue mussel *Mytilus edulis* and some of the ephemeral algae may be harvested. In the past *Sertularia* spp. of hydroids have also been harvested on a commercial scale for use in decorations (Bergahn & Offermann, 1999) but demand is considered to have ceased and the activity is not known to occur in the UK.

The key characterizing *Ulva* spp. may be collected from the wild for use in pharmaceuticals and food. Removal of this species in high quantities would alter the character of the biotope, reduce the food resource available for grazers and reduce shading and habitat structure in pools. The effects of targeted collection of *Mytilus edulis* on mussel beds were recently reviewed by

Mainwaring *et al.* (2014) and are summarised here as the evidence and conclusions are relevant to this biotope which contains mussels and may occur within or adjacent to mussel beds (Connor *et al.*, 2004).

Littorinids are one of the most commonly harvested species of the rocky shore. Experiments designed to test the effects of harvesting by removing individuals at Strangford Lough found that there was no effect of experimental treatments (either harvesting or simulated disturbance) on *Littorina littorea* abundance or body size over a 12 week period (Crossthwaite *et al.*, 2012). This suggests that these animals are generally abundant and highly mobile; thus, animals that were removed were quickly replaced by dispersal from surrounding, un-harvested areas. However, long-term exploitation, as inferred by background levels of harvest intensity, did significantly influence population abundance and age structure (Crossthwaite *et al.*, 2012). A broadscale study of harvesting in Ireland using field studies and interviews with wholesalers and pickers did suggest that some areas were over harvested but the lack of background data and quantitative records make this assertion difficult to test (Cummins *et al.*, 2002). Large scale removal of *Littorina littorea* may allow a proliferation of ephemeral algae, such as *Ulva*, on which it preferentially feeds. The community structure within the biotope is likely to be altered but some individuals are likely to remain.

Dredging for *Mytilus edulis* occurs on both subtidal and intertidal soft sediment, commercial removal of mussels can often be responsible for the depletion of mussel stocks (Atkinson *et al.*, 2003; Dolmer *et al.*, 1999). As the majority of the mussel beds that are harvested in the UK are regularly replenished with seed, the recovery rate for maintained beds should be rapid. In natural (wild) beds, the recovery could be significantly longer due to indirect effects from wave action and the sporadic nature of recruitment (Paine & Levin, 1981; Seed & Suchanek, 1992). *Mytilus edulis* are regularly hand collected from intertidal beds for food and bait which can result in significant damage to the bed (Holt *et al.*, 1998; Smith & Murray, 2005). Smith & Murray (2005) examined the effects of low level disturbance and removal on an extensive bed of *Mytilus californianus* (composed of a single layer of mussels) in southern California. They observed a significant decrease in mean shell length and mussel mass and density, with a loss of 57% coverage, due to the low-intensity simulated bait-removal treatments (2 mussels / month) for 12 months (Smith & Murray, 2005). Additional mussels were lost between experimental 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). In addition, Holt *et al.*, (1998) recorded an incident of the removal of an entire bed that is adjacent to a road in Anglesey due to fishermen bait collecting.

Sensitivity assessment. In general collectors will be efficient at removing *Ulva* spp., *Littorina littorea* and *Mytilus edulis* where targeted and, resistance is therefore assessed as 'Low' (removal is not considered to be total as smaller individuals may escape). Recovery (of the biotope) is assessed as 'High' based on the opportunistic life history of *Ulva* spp. and the evidence of Crossthwaite *et al.*, (2012) for *Littorina littorea*, so that biotope sensitivity is assessed as 'Low'. This assessment refers to a single collection event, long-term harvesting over wide spatial scales will lead to greater impacts, with lower resistance and longer recovery times. Intense harvesting of littorinids would be likely to result in enhanced algal growth although the mobility of the substratum may prevent the establishment of longer-lived algae. Where the pool occurs in *Mytilus edulis* beds and is maintained by their presence, the biotope will be sensitive to their removal and recovery will be dependent on the recovery of the bed. Based on the available evidence all *Mytilus edulis* bed biotopes were considered by Mainwaring *et al.*, (2014) to have 'Low' resistance to this pressure and 'Medium' resilience so that sensitivity is assessed as 'Medium'.

Removal of non-target species**Low**

Q: Low A: NR C: NR

High

Q: High A: High C: High

Low

Q: Low A: Low C: Low

Incidental removal of the characterizing hydroid, *Ulva* spp. and littorinids would alter the character of the biotope. The ecological services such as primary and secondary production provided by these species would also be lost.

Sensitivity assessment. Removal of a large percentage of the characterizing species would alter the character of the biotope, so that it was bare rock. Resistance is therefore assessed as 'Low' and recovery as 'High' and sensitivity is therefore assessed as 'Low'.

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